VOL-XVI NO-3

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

MARCH 1925

SOCIETY OF AUTOMOTIVE ENGINEERS INC.
29 WEST 39TH STREET NEW YORK

There is no Denying Pliant, Deep-Cushion Front Springs

They are coming fast and they are coming to stay

MOST riding complaints come from the passengers on the rear seat. This has led to a focusing of attention on the rear springs and, as a result, our rear springs have been made sufficiently pliant and deep-cushion for maximum riding comfort. But even so, the rear seat passengers are still complaining.

Rear seat "jiggle" and "back slapping" are due entirely to the inaction of the *front* springs. You can prove this by sitting in the rear seat of your car and having some one or two men bounce the front end of the car by standing on the front cross member. With stiff and unyielding front springs, every little inequality in the contour of the road is transmitted directly to the car frame and causes the frame to follow these irregularities. This causes the same up and down movements which were caused by the two men.

Pliant, deep-cushion front springs will immediately alter the riding qualities of the entire car. These pliant springs will absorb the inequalities and allow the front end of the car to be unaffected by them. And with the front end quiet so will the rear end be quiet.

Front springs should be given a cushion of at least 4 inches, 5 inches if possible, (rubber bumper to frame) and the rate of these front springs should be from 200 pounds to 275 pounds, depending upon the weight of the front end of the car. The greater activity of these pliant springs will demand adequate, proportional control against excessive rebound, but devices to do this work can now be had.

President

John Warren Watson Company
Twenty-fourth and Locust Streets
Philadelphia

(*Detroit Branch:* 51-53 Canfield Avenue, East)

WATSON STABILATORS

The Proper Control for Pliant Springs

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. XVI March, 1925 No. 3

Chronicle and Comment

Burkhardt Manager of Research Department

WE are pleased to announce that O. M. Burkhardt has been appointed Manager of the Research Department of the Society, in succession to J. A. C. Warner who is now in charge of the Meetings and Sections Department.

Mr. Burkhardt is well qualified by engineering education and experience for the work of his new position. He has been an earnest and effective participant in various matters related to scientific progress in the automotive field. Among the many papers and articles he has written in the last 15 years are those entitled Analysis of Forces and Contact Conditions in Worm Gearing; Engine Torque, Its Action and Reaction; Analysis of the Functions of Cam-Actuated Valves; Transmission Gear-Reduction Ratios, Geometric versus Arithmetic Progression; Progressive and Retrogressive Designing; Evaluation of Engine Performance; Problems of Crankshaft Design; and Wheel Shimmying—Its Causes and Cure.

For over a decade Mr. Burkhardt has been associated with the Pierce-Arrow Motor Car Co., serving in the capacity of consulting engineer in recent years. He has done much good work as a member and officer of the Buffalo Section of the Society, his efforts having been conspicuously successful in the securing for presentation of timely papers of marked engineering merit.

Production Meeting and Machine-Tool Show

THE 1925 Production Meeting of the Society will be held in Cleveland during the week of Sept. 14. This is the week of the annual convention of the American Society for Steel Treating there, and also of the machine-tool exhibit to be held in connection with the steel show. An authority has declared that the predecessor of this show included the finest exhibit of high-grade production machine-tools he had ever seen. It is said that the demand for exhibit space in the machine-tool show is greater than ever before.

There has been considerable expression of opinion favorable to the Society's holding a Production Meeting concurrently with a show. It is believed that such a course will add greatly to the value of the meeting. Suitable arrangements will be made to avoid conflict of the show or of the American Society for Steel Treating sessions with the sessions of the Society.

First Pan-American Standardization Conference

AS mentioned in previous issues of THE JOURNAL, the first Pan-American Standardization Conference was held at Lima, Peru, Dec. 23, 1924, to Jan. 7, 1925. Kirke K. Hoagg, who represented the Society at the conference, returned to this Country recently. He reported that, while no definite standards were formulated, a satisfactory general basis was decided upon for the establishment in the future of standards mutually agreeable and beneficial to all Pan-American countries.

It was decided that the next Conference will be held in this Country in about 3 years. A general spirit of helpful cooperation was shown at the meeting at Lima.

Aeronautic Meeting Plans

AERONAUTICS will play an important part in Society activities during the present year. The Meetings Committee at its recent session decided to hold an aeronautic meeting of national scope in addition to the sessions on aeronautics that are customarily included in the program of regular meetings of the Society.

The Dayton Section has already formulated plans that will contribute largely toward the success of the Aeronautic Meeting which will convene in Dayton. Presentation of the Wright Bros. Medal by the Dayton Section will be a feature. The award paper, as well as others of outstanding interest, will be delivered. This meeting will undoubtedly be one of the big events of the year.

Part II, 1923 Transactions

WHEN this issue of THE JOURNAL went to press, copies of Part II of Vol. 18 of the TRANSACTIONS had been mailed to the 622 members who had placed orders for them. The papers presented at the 1923 Semi-Annual Meeting, at the Service and the Production meetings of the Society held in the latter half of that year and at Sections meetings and printed in the July to December, 1923, issues of THE JOURNAL inclusive, 29 in all, that were considered by the Publication Committee to possess sufficient engineering value to warrant reprinting are included in this Part of the TRANSACTIONS,

together with such discussion of the papers as was offered following their presentation or subsequently contributed. The volume consists of 812 pp.

Service Meetings

SERVICE matters occupy a place of prominence in the meetings program for the present year. Together with several other automotive bodies of national scope, notably the National Automobile Chamber of Commerce, the Society will act as a sponsor for the Automotive Service Convention and Maintenance Equipment Show that is to be held in Detroit on May 20 to 23.

In November the annual Service Engineering Meeting will convene at a place not yet determined. Both these gatherings promise to afford a wealth of valuable information and opportunities for discussion that service men cannot afford to miss.

Details pertaining to these meetings appear on p. 267 of this issue of THE JOURNAL. Further information will be presented from time to time in these columns.

Tractor Meeting in April

TRACTOR-ENGINE research, lubricating oils and systems, cooling problems and many other topics of interest to tractor men will be considered in detail at this year's Tractor Meeting which will undoubtedly be one of outstanding interest.

Chicago has again been chosen as the site of the meeting. The sessions will be held in the Great Northern Hotel on April 29 and 30, the morning and afternoon events of the latter day being under the auspices of the Society of Automotive Engineers, whereas those of the 29th are being arranged by the American Society of Agricultural Engineers with which the Society is cooperating.

Further particulars are presented on p. 267 of this issue of THE JOURNAL. Additional information will be published in the April issue.

S.A.E. Oil Specifications Revised

ACTION taken at the meeting of the S.A.E. Lubricants Division, as reported on p. 266 of this issue, indicates that better progress will be made in the near future toward more general adoption of the S.A.E. Oil Specification Numbers throughout the industry.

Lack of agreement as to the viscosity of oils of the same grade-name has been and still is the cause of considerable confusion among automobile owners. This often results in the use of oil for which engines are not designed.

President Horning has followed closely the work of the Society in lubricating oil standardization and is extremely interested in seeing the S.A.E. Specification Numbers generally adopted. He believes that every member of the Society should give the adoption of these specifications his earnest consideration.

Oil and Gas Power Week

BY simultaneous technical sessions and discussions to be held about April 20 to 25, it is the purpose to focus the attention of physicists, chemists, engineers and operating and industrial men on recent progress and possibilities in the oil and gas power field. It is the intention that meetings shall be held at various places in the Country on a number of subjects including fuels, engine design, operation, economics and research problems. A number of Government bureaus and engineering societies, including this Society, are participating in the movement in a general way. The committee in charge suggests that as possible and convenient Sections of the various Societies and other local engineering organizations join in the effort in their territory. Some local organizations have already settled upon dates for their meetings within the week mentioned or at about the same time. Detail information has been sent to the officers of the local organizations by the National Committee in Charge, the secretary of which is W. E. Bullock, 29 West 39th Street, New York City. Dr. W. F. Durand, president of the American Society of Mechanical Engineers, is the chairman of the Committee.

Sectional Committee to Study Steel Specifications

THE Sectional Committee on Numbering of Steels, sponsored by the American Society for Testing Materials and the Society of Automotive Engineers, was organized for the purpose of developing if possible a numbering system for forging, casting and structural steels, including plates, to be based on definite specifications. Preliminary consideration of the project covering national use of steels has not indicated any general demand for such a system but a desire is evidenced to simplify the vast number of specifications that are in use by the steel consuming industries of the Country, as the first step toward making a universal numbering system possible.

At a meeting of members of the Sectional Committee in New York City on Feb. 17, the situation that exists with regard to specifying steels was discussed in general and the decision reached that before any further progress can be made toward formulating a system of numbering, definite information is needed as to the specifications in use and the extent to which they overlap and differ for the steels used in large quantities. A subcommittee consisting of Prof. A. H. Beyer, chairman, representing the American Society of Mechanical Engineers; George L. Norris, the Society of Automotive Engineers, and F. W. Olcott, the Federal Specifications Board, was appointed to make such an investigation and report to the Sectional Committee. This work will probably be carried on by the Subcommittee through the larger National organizations represented on the Sectional Committee. Those in attendance at the Sectional Committee meeting were Lieut-Com. G. A. Zimmerman, vice chairman of the Federal Specifications Board; L. H. Fry, secretary of the Sectional Committee and representative of the American Society for Testing Materials; Prof. A. H. Beyer, American Society of Mechanical Engineers; W. R. Edwards, American Railway Association; H. L. Morris, American Society for Steel Treating; R. S. Burnett, of the Society of Automotive Engineers, and W. H. Faus, engineering department of the New York Central Railroad.

AUTOMOTIVE RESEARCH

The Society's activities as well as research matters of general interest are presented in this section

INTERESTING MATERIAL COLLECTED

Riding-Qualities Bibliography Contains 18 Sections and 534 References

A bibliography on the riding-qualities of automobiles has recently been prepared and published in loose-leaf form by the Research Department. The table of contents is here reproduced to show the variety of topics covered:

Balance
Body
Brakes
Chassis
Engine and Transmission
Instruments
  Accelerometers
  Decelerometers
  Impact
  Integrator
  Miscellaneous
  Oscillation
  Photographic
  Profilometers
  Roll
  Torsion
  Vibration
Methods of Test
Psychological and Physiological
Riding-Comfort
Roads
Seating
Shock-Absorbers
Springs
Steering-Gear
Tires
Torque
Vibration
Wheels

Some of the interesting features of the bibliography are: (*a*) 67 references on brakes; (*b*) 150 on springs; (*c*) 27 on steering-gear; and (*d*) 120 on instruments, 53 of which relate to vibration-measuring instruments. Most of the references on instruments have been abstracted for the convenience of the reader.

A copy of the bibliography or any portion thereof may be obtained by writing to the Research Department.

AIR-TEMPERATURE RISE IN RADIATORS

Computation Made at Bureau of Standards Contains Interesting Facts

Designers of radiators for motor vehicles may be interested in certain results deduced from the data contained in Bureau of Standards Technologic Paper No. 211 on Radiators for Aircraft Engines. The relation of heat dissipation to airflow is there shown for 66 different aircraft radiators, representing all the types in common use for motor vehicles, the conditions of all tests being such as to maintain a difference of 100 deg. fahr. between the temperature of the entering air and the mean temperature of the water in the radiator. In that paper the heat dissipation is given as $H =$ horsepower per square foot per 100 deg. fahr., and the mass air flow as $M =$ lb. per sec. per sq. ft., so the rise in temperature is $\triangle t = .707\ H/M$. Assuming an air flow through each radiator of 1.5 lb. per sec. per sq. ft. of frontal area, the rise in temperature of the air passing through the radiator has been computed. The assumed mass air-flow corresponds, in the case of each radiator, to an air speed greater than 20 and less than 45 m.p.h.

TABLE 1—AIR-TEMPERATURE RISE DATA FOR AIRCRAFT RADIATORS

Number of Radiators	Type of Cell	Range of Depth, In.	Rise of Temperature, Deg. Fahr. Average	Maximum	Minimum
21	Square	2⅜— 5	6.2	9.3	3.4
17	Hexagon	2 — 9	5.6	8.7	3.1
14	Circular	2⅞—10	6.1	9.4	4.5
14	Miscellaneous	1¾—23¼	7.1	11.7	4.2

For the entire group of 66 radiators the average temperature of the air leaving the radiator was 6.2 deg. fahr. above the entrance air-temperature when the latter was 100 deg. fahr. below the mean temperature of the water in the radiator. The least rise was 3.1 deg. fahr. and the greatest was 11.7 deg. fahr. as given in Table 1.

Considerable differences in rate of water circulation and moderate differences in rate of air-flow have little effect compared with the influence of radiator design. For the group considered, the average temperature-rise was found surprisingly constant and the effect of depth was largely masked by other factors in design.

AUTOMOBILE PAINTING AND FINISHING

Members Interested in This Topic Are Referred to Pertinent Articles

Inquiries are received from time to time regarding the new automobile finishes. Sometimes the question relates to pyroxylin enamels in general; at other times information is requested about an enamel produced under one or another of the various trade names. In an endeavor to furnish the desired data, the Research Department has assembled a number of references to published articles on this topic. No claim of completeness is made for this list of references, which is here reproduced for its probable interest to members who would like a general rather than an exhaustive knowledge of the subject.

ARTICLES IN THE JOURNAL

Revolutionary Painting Methods. January, 1924, p. 90.
Pyroxylin Enamels Finding Favor. March, 1924, p. 352.
Paint Durability Being Increased. April, 1924, p. 380.
Causes of Paint Failures. May, 1924, p. 479.
Refinishing of Automobile Bodies. June, 1924, p. 571.

ARTICLES IN OTHER TECHNICAL JOURNALS

New Product May Solve Body Finishing Problem. By O. H. Briggs. *Automotive Manufacturer*, August 1923, pp. 12-13.

Labor Costs Halved by Use of Duco in Finishing Oakland Bodies. By W. L. Carver. *Automotive Industries*, Sept. 13, 1923, pp. 524-525.

Egyptian Lacquer Develops New Nitro-Cellulose Automobile Finish. By Herbert Chase. *Automotive Industries*, April 10, 1924, pp. 828-829.

New Valentine Varnish System Said To Double Life of Finish. *Automotive Industries*, May 1, 1924, pp. 968-969.

Demand for More Durable Finishes Stimulates New Developments. *Automotive Industries*, May 1, 1924, pp. 978-981.

Egyptian System Gives Finish in 1 Week. *Motor Vehicle Monthly*, June, 1924, p. 38.

Zapon Pyroxylin Finishes Now Ready for Use in Body Production. *Automotive Industries*, July 10, 1924, p. 121.

Low-Bake Enamels for Automobile Finishing. By D. R. Bragdon. *Autobody*, July, 1924, p. 18; also, *Motor Vehicle Monthly*, July, 1924, p. 37.

High-Bake Enameling of Automobile Bodies. By Albert I. Stevens. *Autobody*, July, 1924, p. 20; also, *Motor Vehicle Monthly*, July, 1924, p. 38.

Pyroxylin Enamels for Body Finishing. By E. M. Flaherty. *Autobody*, July, 1924, p. 15; also, *Motor Vehicle Monthly*, July, 1924, p. 34.

All Seven Coats of New Pyroxylin Finish (Valenite) Applied in 2 Days. By Herbert Chase. *Automotive Industries*, July 31, 1924, pp. 254-255.

The New Pyroxylin Automobile Finish. By Sidney D. Kirkpatrick. *Chemical and Metallurgical Engineering*, Aug. 4, 1924, pp. 178-182.

Beckwith-Chandler Pyroxylin Automobile Finish (Neolite). *Motor Vehicle Monthly*, September, 1924, p. 40; also, *Automotive Industries*, Aug. 14, 1924, p. 324.

What Pyroxylin Finishes (Duco, Egyptian Lacquer, Zapon, Valenite, Mimax, Neolite) Mean to the Repairman. *Motor World*, Aug. 21, 1924, pp. 26-27.

Automobile Finishing by Valspar Enamel System. *The Automotive Manufacturer*, September, 1924, p. 8.

Valentine Nitro-Cellulose Finishing System. *Motor Vehicle Monthly*, September, 1924, p. 36.

Final Coat of Latest Pyroxylin Finish (Mimax) Gives Gloss without Polishing. *Automotive Industries*, Sept. 18, 1924, p. 526.

Notes on Pyroxylin Finishes and Their Application. By M. C. Hillick. *Motor Vehicle Monthly*, November, 1924, p. 34.

Nitro-Cellulose Finishes on Commercial Vehicles. By M. C. Hillick. *Motor Vehicle Monthly*, November, 1924, p. 38.

Easy Polishing Is Feature of New Lacquer Finish (Prodium). *Automotive Industries*, Nov. 13, 1924, p. 849.

Latest Lacquer Finish Is Termed Berryloid. *Automotive Industries*, Feb. 12, 1925, p. 264.

PERSONNEL OF HIGHWAYS COMMITTEE

It is regretted that through a typist's error, the name of S. H. Woods was omitted from the personnel of the Highways Committee, printed in these columns last month. The following compose the Highways Committee:

B. B. Bachman, *Chairman*

R. S. Begg — W. E. Lay
H. C. Dickinson — C. M. Manly
S. H. Woods

THE INQUISITIVE RESEARCH MIND

Sound and Penetrative Thinking Needed in Both Pure and Applied Research

The application of research methods to an important industrial problem is the theme of an article on Rubber Latex, by Dr. B. J. Lemon, that was published in *The Cornell Chemist*, September, 1924. Because of their undoubted interest to all who read these columns, Dr. Lemon's introductory remarks on research are reproduced in the following paragraphs:

Research—Pure and Applied

Saying something new about research is like going out of doors early in the morning to take a turn about the garden. You think you are catching the day at the start; it is already old to the birds. It is a difficult task to give newness to old things, for however self-satisfying one's own musings on research, all has been said before. Research is no longer a word familiar only to scientific workers and writers. It is in the mouth of almost every man on the street and a by-word of all news editors.

In the early days, lines were sharply drawn between the fundamentalists representing pure scientific research and the modernists representing mercenary industry. Even today there is some hair-splitting among those on the one hand whose sole aim is a deeper understanding of the underlying principles and theories of nature, and those on the other hand who deal with the properties of commodities connected with production and distribution.

While it is a curious fact in the history of science that many of the greatest discoveries have been made by those not thinking of practical application, yet since the sunrise of industrial development, battalions of able investigators have demonstrated that the peculiar information-seeking state of mind, the absolute honesty and integrity of purpose required of a research worker, may be as successfully cultivated in industrial laboratories as they were once discovered or developed in university circles.

Research—Sound and Unsound

In looking over the two fields for shortcomings, there is one particular evil to which the fundamentalist in research is not so likely to yield, namely, the habit of steaming along on superficial discoveries broadcast by cleverly worded advertisements. Examples are not wanting when startling announcements are made, in nationally circulated periodicals, of discoveries that long have been common practice in production fields. In the absence of a Judge Landis, such travesties on the priority of research can and should be brought up short by workers in pure science or others who are unfettered by industrial etiquette. For such pretending scientists have not eagerly searched for a fact or theory. They are seeking to fool the uninformed, and should be shown no quarter.

It is still to pure science that we in the industries must look for ideals. The fundamentalists in science may not establish as facts all of their theories, any more than the religious literals are likely to establish the literacy of the Bible. It is not so important that they do. But if they push their attack on the short-cut modernists often enough and with vigor, they will establish in industrial laboratories an inclination to find out what is truly worthy of being classified as industrial scientific research. To think scientifically is what we are all coming to, and the sooner the better. In both pure and applied research we need sound and penetrative thinking, such scientifically guided thinking as has not been always abundant in some of our industrial laboratories.

To attack properly a comparatively simple problem of investigation requires much ingenuity and an enormous amount of difficult work. When the solution is reached, however, the general and economic results are frequently very great.

STANDARDIZATION ACTIVITIES

The work of the Divisions and Subdivisions of the S. A. E. Standards Committee and other standards activities are reviewed herein

PROPELLER-SHAFT STANDARD NOT USED

D. F. Kalish States 234 Special Designs of Shaft-Ends Are Now Being Produced

Considerable time and effort was spent by the Truck Standards Division in 1922 on the standardization of the shaft-end on the midship mountings of three-joint propeller-shafts which resulted in the adoption of the present S.A.E. Recommended Practice for Three-Joint Propeller-Shafts, p. E6b of the S.A.E. HANDBOOK, which is reprinted herewith.

Up to the present time truck manufacturers have not availed themselves of the benefits that would obtain by the general use of this recommended practice in their regular production. As a result, the manufacturers of universal-joints have been, and still are, called upon to make a new shaft-end for practically every model of truck that is built.

THREE-JOINT PROPELLER-SHAFTS

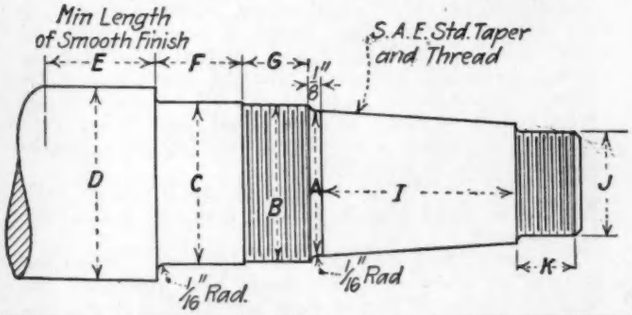
S.A.E. Recommended Practice

The front-shaft rear shaft-ends on which the center bearing is mounted, of long-wheelbase motor trucks, shall be in accord with the S. A. E. Standards for taper or spline fittings, pp. C14 and C18.

The following S. A. E. Standard annular ball bearings of the medium series, p. C28, shall be used on the shaft-ends.

Shaft-End, In.	Bearing, No.
1¼	307
1⅜	308
1½	309
1¾	310
2	311

PROPELLER-SHAFT TAPER SHAFT-ENDS



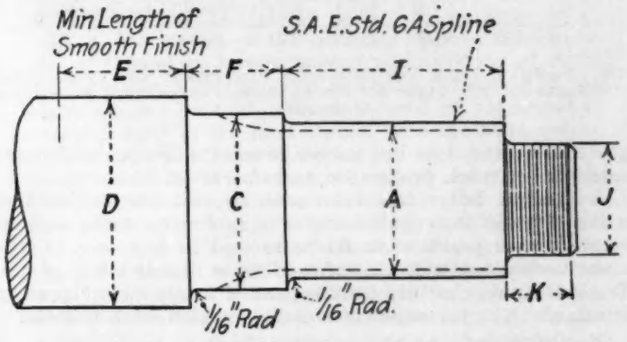
Nominal Diameter[1]	A	B-Diameter and Thread	C	D	E	F	G	I[2]	J[2]	K[2]
1¼	1.251 1.249	1⅜–18	1.378 1.377	1 11/16	1	41/64	5/8	1⅜	1–20	11/16
1⅜	1.376 1.374	1½–18	1.575 1.574	1⅜	1 1/16	41/64	5/8	1⅜	1–20	11/16
1½	1.501 1.499	1⅝–16	1.772 1.771	2 1/16	1⅛	49/64	¾	1⅜	1–20	11/16
1¾	1.751 1.749	1⅞–16	1.968 1.967	2¼	1 5/16	1	¾	2⅛	1¼–18	13/16
2	2.001 1.999	2⅛–16	2.166 2.165	2 7/16	1¼	1 1/16	¾	2⅞	1¼–18	13/16

Taper per foot: 1.500 + 0.005 in.
[1] All dimensions in inches.
[2] As specified in the S.A.E. Standard for Taper Fittings, p. C14. With this type of construction, it is intended that the packing shall bear on the ground surface of the universal-joint hub.

Self-aligning bearings provided for taking radial loads only shall be used for supporting the rear shaft-end. All thrust loads shall be carried by the transmission and the rear axle.

The bearing shall be clamped to the shaft in accord with good bearing-mounting practice.

PROPELLER-SHAFT SPLINE SHAFT-ENDS



Nominal Diameter[1]	A	C	D	E	F	I[2]	J[2]	K[2]
1¼	1.250 1.245	1.378 1.377	1 11/16	1	41/64	1 7/16	1–20	11/16
1⅜	1.375 1.370	1.575 1.574	1⅜	1 1/16	41/64	1 11/16	1–20	11/16
1½	1.500 1.495	1.772 1.771	2 1/16	1⅛	49/64	1 11/16	1–20	11/16
1¾	1.750 1.749	1.968 1.967	2¼	1 5/16	1	2 1/16	1¼–18	13/16
2	2.000 1.995	2.166 2.165	2⅜	1¼	1 1/16	2 11/16	1¼–18	13/16

Spline fitting dimensions shall be as specified in the S.A.E. Standard for 6A spline fittings, p. C18.
[1] All dimensions in inches.
[2] As specified in the S.A.E. Standard for Taper Fittings, p. C14.

The chart shown in Fig. 1 shows clearly the rapid increase in the number of designs that the Spicer Mfg. Corporation alone has been obliged to make during the period of from 1918 to 1924, according to Mr. Kalish. This chart shows that the requirements increased from 7 sizes in 1918 to a total of 234 sizes in 1924.

Although the S.A.E. Recommended Practice was established in 1922, no resulting decrease in the number of sizes is indicated by the chart. While the S.A.E. Standard covering 10 sizes of shaft-ends was adopted in 1922, these sizes were not adopted in practice and 98 new sizes were ordered during 1923 and 1924.

An analysis of the 234 different designs produced in 1924 shows clearly that with the exception of a few special designs, slight changes in the housing for the center-bearing support would permit the large number now in use to be materially reduced, but there is no reason why the truck manufacturers could not have adopted the S.A.E. Standard sizes at the time the original designs were established.

Under present conditions, the shaft-ends cannot be manufactured in quantity and are made only in small lots in accordance with actual shipping releases against the truck manufacturers' orders. This adds greatly to the expense of

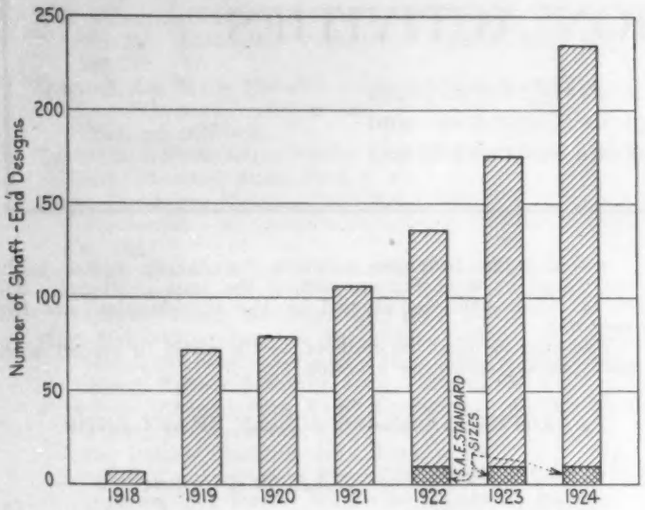


FIG. 1—SHAFT-ENDS FOR MID-SHIP MOUNTINGS OF THREE-JOINT PROPELLER-SHAFTS MADE BY SPICER MFG. CORPORATION FROM 1918 TO 1924

production, and does not permit prompt deliveries which are essential in truck production and operation.

A general letter has been sent to motor-truck builders using three-joint propeller-shafts to determine if the present recommended practice should be revised in any way. Criticisms submitted will be referred to a Subdivision of the Truck Division that has been appointed to review the present standard. The personnel of this Subdivision is as follows:

A. F. Scaife, *Chairman*	White Motor Co.
N. R. Brownyer	Gotfredson Truck Co.
G. A. Green	Yellow Coach Mfg. Co.
J. C. Haggart, Jr.	Republic Motor Truck Co.
M. C. Horine	International Motor Co.
D. F. Kalish	Spicer Mfg. Corporation
M. P. Stoney	Merchant & Evans
F. A. Whitten	General Motors Truck Co.

STANDARDIZATION POLICY DETERMINED

Action Taken by Special Committee Regarding Procedure When Patents Are Involved

The Special Committee recently appointed by the Council of the Society to draw up a definite standardization policy held its first meeting in New York City on Jan. 6. At this meeting the Society's Constitution and the By-Laws were reviewed with reference to restrictions on standardization of parts or materials covered by patents. It was generally agreed that there is nothing in either the Constitution or By-Laws that would restrict the Society in this connection.

After a general discussion of the situation, Mr. Horning submitted the following outline for the standardization policy:

(1) Whether or not a part or material is patented shall not influence its standardization

(2) Standardization, whether involving patents or not, shall be undertaken only when the part or material is in general use or about to be adopted in general practice

(3) Primarily, those details shall be standardized which promote interchangeability between parts, eliminate needless sizes and specifications or facilitate production

(4) Where it is known that a standard is covered by a patent, the notice of the non-responsibility of the Society shall be included in the standard

(5) A general notice covering possible unknown patent cases shall be printed in the S. A. E. HANDBOOK

(6) Where a patent is not adjudicated, the subject shall be considered by the Council which may assign the points involved to a special committee of the Council or the Patents Committee for consideration and recommendation

At a meeting of the Committee in Detroit on Jan. 19, this outline was approved as a tentative basis for the S. A. E. Standardization Policy.

The Committee also considered whether the Society's standards activities should be limited to only the formulation and publication of standards or whether it should interest itself in furthering the reduction to practice of standards that are adopted. It was the general consensus of opinion that the Standards Department should undertake to further the adoption of the standards in practice.

Those present at the meeting on Jan. 6 were H. M. Crane, chairman; B. B. Bachman, H. L. Horning, E. A. Johnston, C. M. Manly, C. F. Clarkson, R. S. Burnett and C. E. Heywood. C. B. Whittlesey was also present at the Jan. 19 meeting.

LICENSE-PLATE STANDARD PROPOSED

R. M. Hudson Believes Standard Should Be Adopted by State Authorities

In an extensive survey of the possibilities and desirabilities of standardizing license-plates, R. M. Hudson, chief of the division of simplified practice of the Department of Commerce, recommends that a National standard for automobile license-plates should be adopted by the State authorities.

The present S. A. E. Standard for License-Plate Bracket-Slots specifies two 9/32-in. slots 3 in. long placed so as to allow for mounting plates with the bolt-holes from 4¼ to 10¼ in. apart. This standard will be included in the March issue of data sheets.

The following abstract of the survey issued by the Division of Simplified Practice gives the more important and interesting features outlined:

The license plate serves two major purposes, registration and identification. The purpose of this article is to show that both of these purposes can be adequately served with standardized plates, standard in all features except color, name of issuing State and year issued. Plate, letter and numeral sizes, gage of metal, punching, mounting brackets, location and degree of illumination at night can all be standardized with benefit to State and municipal authorities, plate makers, car builders, accessory manufacturers, motorists and even to pedestrians.

To illustrate the possibilities in this direction, each feature to which standardization may be applied will be discussed.

Standard Plate Punching and Mounting. When the Society of Automotive Engineers first attempted the standardization of license-plate punching, it found difficulty in having its recommended standard adopted by the State motor-vehicle authorities. The only practical alternative, therefore, was to specify mounting bracket slots of sufficient length and width to accommodate as many different State plates or tags as possible within a reasonable degree of variation in punching. The bracket slots proposed by the Society of Automotive Engineers are each 3 in. long and 9/32 in. wide and it is known they will accommodate without difficulty the plates of 46 of the 48 States, Louisiana and Mississippi plates not having been checked.

Standardization of plate punchings would permit the revision of the recommended mounting-bracket standards to specify either shorter slots or only holes. This in turn would accelerate the adoption and installation of standard mounting-brackets by car builders as standard equipment on their cars, and help the accessory manufacturers in producing standard tail-lamps.

At the suggestion of the Society of Automotive Engineers, the division of simplified practice of the Department of Commerce took up the matter with the motor-vehicle authorities in each State. The division pointed out that through uniformity in the punching of the plates and the slots or holes in the brackets, the plates of any State would fit the brackets on any car. This would not only be a convenience to the car builders, but also to the automobile dealers and the motoring public. It would facilitate or accelerate the establishment of a standard method of display, including not only a standard location on the car, but also a relatively standard degree of visibility at all times. Replies from over two-thirds of the States favored standardizing the punchings. None of them opposed the idea. Though State laws define other tag features with great exactitude, there are no State laws governing the punchings of the plates. Because of this freedom of choice on the part of the State motor-vehicle authorities, it should be relatively easy to standardize on plate punchings which would permit the Society of Automotive Engineers to reduce its present bracket slot lengths from 3 to 1 in., or even to ½ in.

From statements made by both the State authorities and the plate makers, it appears there is no good reason why standard plate punchings and standard mounting-bracket slots, or preferably holes, should not be adopted by all concerned. Such cooperative action would eliminate the mutilation or defacing of plates often resulting from the necessity of putting holes through the plate at points other than those originally provided.

Standard Size of Plate Symbols.—Variation in sizes of numerals, letters and other details is very pronounced. State laws differ widely on these dimensions. This variation cannot help but cause difficulty to those whose duty it is to watch licenses on passing cars. There is no doubt a normal minimum letter or digit size that might well be adopted as standard for all plates.

Not infrequently the spacing of the digits is too close, giving a blurred effect to the entire number. Again, the State initials or abbreviations, or the year of issue, encroach on the digits in the license number, thus adding to the confusion. What is the ideal or best minimum spacing or arrangement should also be determined. The arrangement of the abbreviation of the State name is another possible point of standardization. Some appear to the left, others to the right of the license number. Some are relatively large and others small. The location, and also the size, of the type in the abbreviation might well be standardized. Perhaps a better idea is to use the State name spelled out. The 1925 Arizona tag carries the complete State name in fairly large letters and is an excellent example of what might be done in many other cases.

The standardization of the location, and also of the size of the numerals in the year of issue are also worthy of consideration. There seems to be no good reason why the arrangement of all the plate symbols cannot be standardized as to their respective locations.

Standard Gage.—The gage of metal used varies from No. 14 to No. 26. A stiff plate resists bending. The thinner the plate, the less durable it is likely to be. There is no doubt some consistent minimum for this feature. Similarly, sheets of certain grades or qualities resist rust and corrosion better than others. A selection might be made on the basis of a life of 1 year under normal conditions of use as being the lowest quality acceptable.

Standard Size.—In the replies mentioned, standardization of plate size is also suggested. Plates are now made from 8 to nearly 20 in. in length and from 4 to 6 in. in overall width. The smaller the plate, regardless of the color used on it, the more easily it is obscured or its identity shrouded. There is no doubt a minimum size below which a plate should not be made lest ease of identification be destroyed. That minimum size may well be that which the normal eye can readily visualize at normal car-speed.

Standard Code of Numbering.—The variety of numbering codes is nearly as great as the number of license-issuing bodies. Here again is an opportunity for standardizing on a code which is readily understandable by the majority of those concerned. A code letter might well be used to designate a common geographical section, or "sector," in all States. This principle is used in mapping battle-fields and in many other instances.

With such a code, the necessity for unduly long numbers and long plates diminishes. To illustrate, with the 26 letters in the alphabet and numbers running from 1 to 9999, it is possible to care for 259,974 licenses. If numbers run to 99,999, then nearly 2,600,000 licenses can be covered. The shorter the number, the easier it is to remember, and "A-2675" or even "B-98,356" is relatively easier for many people to remember than "1-514-692."

R. A. Brannigan of the National Automobile Chamber of Commerce has suggested that, instead of numbering plates with the usual numbers, the letters of the alphabet also be used. When the end of the series is reached, start in the next column with the same series, and so on. If all the numbers and letters were used, there would be 36 integers instead of the present 10, but it is not very practical to use the full series, because the letter I and the number 1, and the letter O and the number 0 are identical, and moreover, utilizing the full alphabet would mean that certain combinations would spell actual words, which would be objectionable. This objection is readily overcome by eliminating the 1 and the 0, and the vowels, leaving 29 integers or symbols with which to work.

This would mean that there would be 29 license plates with only one symbol; 841 with no more than two; 2439 with no more than three; 707,281 with no more than four; and 20,511,149 with no more than five.

Standard Location.—A recurrent suggestion in the letters to the Division of Simplified Practice is that a standard location, front and rear, should be adopted. Front plates are often obscured by bumpers; rear plates by tire carriers. Plates mounted on fenders are often smashed or bent by the fender crashes now so common in congested areas.

It is certain that standardizing the location of these identification marks would help all concerned with their observance. There would be no "hunting around" to find the tag. It would be plainly visible for a definite number of feet in daylight, and its illumination at night could be more definitely controlled or guaranteed. A standard license-plate location would enable car builders to make suitable provision accordingly.

Standard Illumination.—Assuming a plate of standard size, located in a standard position, and such standards adopted throughout the United States of America, the present great lack of uniformity in night illumination would be largely overcome. The Society of Automotive Engineers and the Illuminating Engineering Society have adopted a tail-light illumination standard. This standard represents what is now legal in Massachusetts, and meets the approval of members of the Eastern Conference of Motor Vehicle Administrators.

Coordination of Color Selection.—A State selecting a color combination seeks to avoid conflict with neighboring States, also with its own "last year's tags," or the obsolete tags of its neighbor. There are only seven basic colors in the spectrum, though there are many shades or tints of each. All these basic colors, as well as black and white, are used in combinations of two, one for the number and the other for the background. The question here is that of the relative visibility of each combination. Perhaps through annual meetings of the officials of the several Conferences of Motor

Vehicle Administrators a coordination of color selections would be possible which would recognize all these problems.

It is obvious that as the importance of the license number is accentuated or emphasized, it will have a definite effect on many would-be reckless drivers. When it becomes easier to get the number of the reckless driver and the possibility of error in reading his number is reduced by standard mounting, standard size and standard illumination, then many a chance-taker is going to drive more sanely.

OIL STANDARD TO BE MORE RESTRICTIVE

S.A.E. Lubricants Division Recommends Higher Oil Viscosities

At a meeting of the S.A.E. Lubricants Division, held in Chicago on Feb. 11, it was proposed that the present S.A.E. Recommended Practice for Crankcase Lubricating Oils be made more restrictive by increasing the requirements for the various specifications. The present S.A.E. Recommended Practice, which is given on p. D151 of the S.A.E. HANDBOOK, revised as proposed at this meeting, is given hereinafter. In the table for the numerical requirements of the various specifications, the requirements now specified are given in parentheses.

The increases in the viscosity and flash and fire-points are proposed by the Division because of the general recognition that the present specifications are so broad that they do not constitute in any way restrictive specifications, but rather general classifications of existing lubricants. As the result, the specifications are not used very generally, but it is recognized that if they had not been purposely made unrestrictive, they would not be used to as large an extent as they are. It is now felt, however, that conditions are such that both the automobile and oil companies desire higher requirements.

It is understood that the use of the S.A.E. Numbers on oil containers is objectionable on the ground that the oil companies would lose the effect of their advertising which has been based on grade and brand names. It was understood, however, that it was not intended that the oil companies should discontinue the use of such names, but that conditions would be clarified if the S.A.E. Numbers were used as supplementary to the grade and brand names.

J. B. Fisher of the Waukesha Motor Co. stated that his company is now casting on the crankcase the number of the S.A.E. Oil that should be used for their engines, grade or brand names not being used in printed matter.

The members of the S.A.E. Lubricants Division present were H. C. Mougey, of the General Motors Research Corporation, chairman; A. B. Dawson, of the General Motors Corporation; J. B. Fisher, of the Waukesha Motor Co.; R. K. Floyd, of the Frank H. Floyd Co.; W. H. Herschel, of the Bureau of Standards; H. J. Saladin, of the Standard Oil Co. of Indiana; and Standards Manager R. S. Burnett.

Others present were Sidney Born, P. I. Johnston and F. D. Shields, of the Transcontinental Oil Co.; C. D. Frieburn, of the Vacuum Oil Co.; C. L. Knopf and S. F. Lentz, of the Sinclair Refining Co.; A. B. Lort, of the Paragon Refining Co.; E. W. Upham, of the Maxwell Motor Corporation; J. L. Murray, of the Corn Belt Oil Co.; E. J. Keitel, of the Columbia Oil Co.; W. A. McMillan, of the Lindsey, McMillan Co.; and Jack Nourse, of the Nourse Oil Co.

Copies of the revised specifications have been sent to automotive vehicle builders and oil producers with a request that further changes in the specifications or criticisms of the changes proposed be submitted to the Society in order that the Lubricants Division may be properly guided in its final action on this matter. Any comments received from other Society members will also be referred to the Lubricants Division.

PROPOSED REVISION OF CRANKCASE LUBRICATING OIL SPECIFICATIONS

General.—These specifications cover grades of petroleum oil for the lubrication of internal-combustion engines, except aircraft, and are not recommended for the lubrication of turbines. Compounded lubricating oils containing products other than those derived from petroleum are not dealt with in these specifications.

Scope and Use.—These specifications are the minimum requirements for each grade of oil. The specification numbers, when used on containers, indicate that the oils therein meet or exceed the minimum requirements specified. The grades of oil included in the specifications are those used in the larger amounts for automotive purposes. Intermediate grades for special purposes may be obtained, but are not governed by these specifications.

Specification No.[1]	Flash-Point, Deg. Fahr., Minimum Cleveland Open Cup	Fire-Point, Deg. Fahr., Minimum	Average Viscosity, Saybolt Universal Sec.				N.P.A. Color No.	Pour Test, Deg. Fahr., Maximum	Conradson Carbon Residue, Per Cent, Maximum
			100 Deg. Fahr.		210 Deg. Fahr.				
			Minimum	Maximum	Minimum	Maximum			
20	275 (325)	420 (365)	180	220	45 (42)	....	5	25 (35)	0.15 (0.20)
020	335 (325)	380 (365)	180	220	43 (42)	....	4	0 (10)	0.20
30	385 (335)	425 (380)	270	330	48 (44)	....	6	35 (40)	0.50 (0.30)
030	340 (335)	385 (380)	270	330	47 (44)	....	5	0 (10)	0.30
50	420 (355)	480 (400)	450	575	60 (50)	....	6[a]	40 (50)	0.80 (0.60)
050	360	410	450	575	53	....	6[a]	10	0.40
65	365	415	...	...	60	70	6[a]	40	0.80
80	385 (380)	435	...	...	73 (75)	85	6[b]	45 (55)	1.50
115	420 (400)	480	...	...	110	120	7[c]	50 (60)	2.00

Figures given in parentheses are as now specified in S.A.E Recommended Practice.

[1] For Specifications No. 20 to 50, inclusive, the numbers indicate the first two figures of the approximate average viscosity, Saybolt Universal, in seconds at 100 deg. fahr. for the grades indicated. The first cipher in Specifications No. 020, 030 and 050 indicates the low temperature pour-test value of these grades. The numbers for Specifications No. 65 to 115, inclusive, indicate the approximate average viscosity, Saybolt Universal, in seconds at 210 deg. fahr.

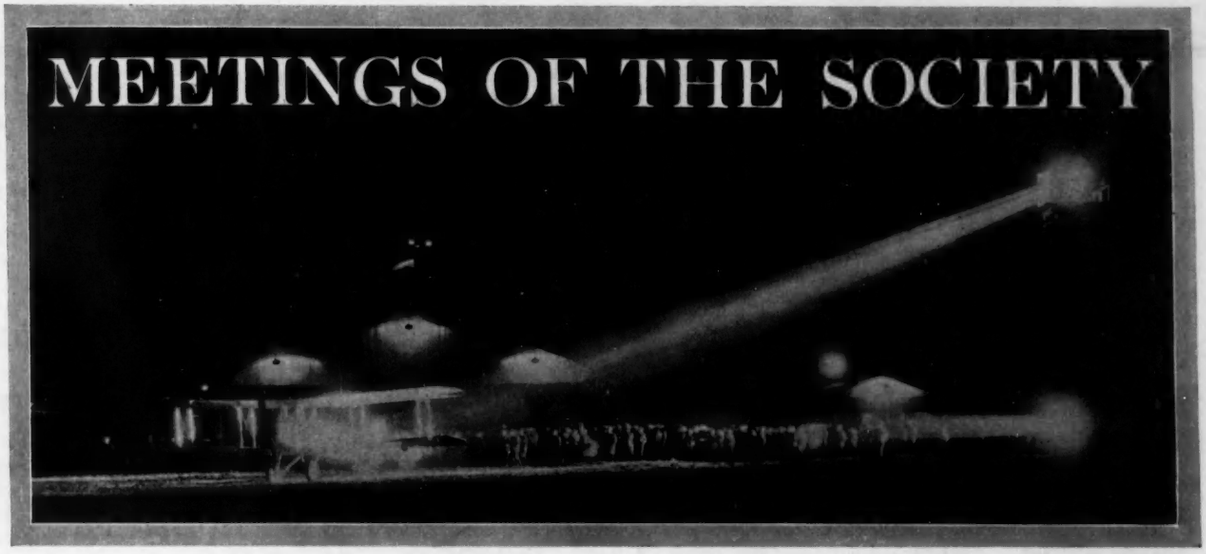
[a] 50 per cent oil and 50 per cent kerosene.

[b] 25 per cent oil and 75 per cent kerosene.

[c] 15 per cent oil and 85 per cent kerosene.

Corrosion Test.—The following corrosion test, required for all specifications, shall not cause the discoloration of copper strip. Place a clean piece of mechanically polished pure strip-copper about ½ in. wide and 3 in. long, and 10 cc. of the oil to be tested, in a clean test-tube. Close the tube with a vented stopper and hold for 3 hr. at 212 deg. fahr. Rinse the copper strip with sulphur-free acetone and compare it with a similar strip of freshly polished copper.

Tests shall be made in accordance with the American Society for Testing Materials Specifications.



TRACTOR MEETING NEXT

Service, Production, Transportation, and Aeronautic Meetings Also Announced

As mentioned briefly in the February issue of THE JOURNAL, the Meetings Committee has formulated plans for an interesting and comprehensive array of national meetings for the year. The various sub-committees are already actively engaged in making arrangements for speakers, exhibits, demonstrations and other important features.

O. B. ZIMMERMAN

The Tractor Meeting will be held this year at Chicago on April 29 and 30 in cooperation with the American Society of Agricultural Engineers. The Agricultural Society will have charge of the sessions of the first day, whereas the sessions on the 30th will be under the auspices of the Society of Automotive Engineers.

President Horning has consented to present an address on tractor-engine research at one of the sessions arranged for the second day by the sub-committee, of which O. B. Zimmerman is chairman. Other competent engineers will discuss cooling and lubricating systems, oils and fuels, and general topics of interest.

The scope of the morning and afternoon sessions of the 29th will include topics involving soil dynamics and matters relating to the application of implements to power-farming. These as well as the subsequent technical sessions will convene at the Great Northern Hotel.

On the evening of the 29th the members and guests of the cooperating societies will enjoy viewing a series of motion pictures applying to both agricultural and automotive engineering subjects.

Informal luncheon gatherings will be addressed by able speakers.

Assisting Chairman Zimmerman in the sub-committee work are W. I. Ballentine, R. T. Hendrickson, H. O. K. Meister, J. F. Max Patitz and O. W. Young.

SERVICE MEETINGS

The Society will again act as one of the sponsors of the Automotive Service Convention and Maintenance Equipment Show initiated by the National Automobile Chamber of Commerce. This event will be held at General Motors Building, Detroit, May 20 to 23, and will include a number of technical sessions in addition to an extensive exhibit of maintenance equipment for garages and service-stations. An exhibit of S. A. E. standards will be included. The problems of the man in the field will be featured at the technical sessions.

In November the Society will again cooperate with the National Automobile Chamber of Commerce in a Service Engineering Meeting. The sessions on one day of the two-day meeting will be handled by the Society. Final plans as to the date and the meeting place will be announced later.

MOTORBOAT MEETING

As yet no definite plans can be announced regarding the annual Motorboat Meeting. It will probably be held at the time of one of the regattas when interested members will be congregated. The fact that T. J. Litle, Jr., chairman of the Meetings Committee, is in charge of the arrangements for this meeting assures it of success.

PRODUCTION MEETING IN CLEVELAND

Unless all signs fail, the 1925 Production Meeting will set a new standard for such events. Cleveland has been chosen as the site and Sept. 15 and 16 as the dates. The annual meeting of the American Society for Steel Treating will also convene in Cleveland during that week, and a cordial invitation has been extended to our members to attend any of its sessions that may be of interest. The two Societies will cooperate in arranging the programs so as to avoid conflict of meetings.

The annual exhibition of machine tools and equipment, a comprehensive affair and one of the outstanding events of the American Society for Steel Treating program, will be among the important features of interest to our members.

Every effort is being made to provide technical sessions at the Production Meeting that will make available to the members a wealth of engineering material of real worth. Exhibits and demonstrations will be featured. Factory visits and a Production Dinner will presumably be included.

AUTOMOTIVE TRANSPORTATION MEETING

Philadelphia will in all probability act as host for the Automotive Transportation Meeting late in September. A. W. S. Herrington and the members of his sub-committee already have the general plans for the meeting well in hand.

AERONAUTIC MEETING

A pronounced demand exists among many of our members for increased Society activity in the field of aeronautics.

NATIONAL MEETINGS CALENDAR

TRACTOR MEETING
Chicago—April 29 and 30

AUTOMOTIVE SERVICE CONVENTION AND MAINTENANCE EQUIPMENT SHOW
Detroit—May 20-23

SUMMER MEETING
White Sulphur Springs, W. Va.—June 16-19

MOTORBOAT MEETING

PRODUCTION MEETING AND EXHIBITION
Cleveland—Sept. 15 and 16

AUTOMOTIVE TRANSPORTATION MEETING
Philadelphia—September

AERONAUTIC MEETING

SERVICE ENGINEERING MEETING
November

ANNUAL DINNER
New York City—January, 1926

ANNUAL MEETING
Detroit—January, 1926

President Horning has indicated a genuine desire to have these matters vigorously supported.

In view of the importance of the subject the Meetings Committee has planned a National Aeronautic Meeting in addition to the usual Annual Meeting session that is customarily devoted to this phase of engineering activity. The exact time and place of the meeting have not yet been definitely determined.

It is expected that the Wright Bros. Medal Award offered annually by the Dayton Section will bring forth material that may be featured.

SUMMER MEETING AT WHITE SULPHUR

Popular Resort To Welcome Members for Engineering Conference and Relaxation

It is certain that members who attended the Summer Meeting at White Sulphur Springs, W. Va., in 1922 will "repeat" *en masse* by assembling at the same delightful resort on June 16 to 19 for the Semi-Annual Meeting this year. Many new enthusiasts will undoubtedly be numbered among those who attend.

The Technical Sessions

Among the topics that will be presented at the technical sessions by able engineers and discussed by interested members are gasoline-electric motorbuses and rail-cars, lubrication and fuel problems, brakes, transmission developments, riding-qualities, noise investigation, and highway safety as it is affected by factors of vehicle design and construction.

It will be noted that these are topics of live interest; their consideration will doubtless prove of great practical worth to the members who attend. In arranging the sessions the Meetings Committee is laying great stress on the importance of presenting material of real engineering value in an attractive manner. Exhibits and demonstrations will add materially to the feature last mentioned.

Hotel Accommodations

The Greenbrier Hotel, remembered for its excellent facilities, service and cuisine, will house the majority of the members, whereas others will prefer the accommodations of the splendid cottages adjacent to the hotel. The rooms and equipment are of the highest order.

Recreation

The possibilities for pleasant relaxation and recreation at White Sulphur Springs are all that can be desired. There are three picturesque and sporty golf-courses, one of 9 holes and two of 18. Five excellent tennis courts lie adjacent to the attractive clubhouse, whose shady verandas provide points of vantage for tennis and golf spectators. A baseball diamond awaits the adherents of the national pastime. Trapshooting, bowling, croquet, clock-golf and quoits are provided for. A spacious lawn near the hotel will accommodate the annual games. A well-appointed swimming pool will be available to those who enjoy the water.

Special arrangements are being made to assure the ladies who accompany the members of a never-to-be-forgotten visit.

Additional information pertaining to the Summer Meeting will be published in later issues of The Journal and in the *Meetings Bulletins*.

RESUME OF ANNUAL MEETING

Pennsylvania Section Shows Interest in Younger's Summary of Detroit Papers

Members of the Pennsylvania Section of the Society who were unable to attend the Annual Meeting at Detroit in January were given a resume of the principal papers at the Section Meeting in Philadelphia on Feb. 10 by John Younger, editor of *Automotive Abstracts*, Cleveland. His address was

ENTRANCE TO THE HOTEL GREENBRIER, WHITE SULPHUR SPRINGS, W. VA.
This Palatial Hostelry Will Again Be the Scene of the Summer Meeting, the Sessions This Year Being Scheduled for June 16 to 19 Inclusive

greeted warmly and keen interest was shown in the program of the Annual Meeting. B. B. Bachman acted as chairman.

Mr. Younger, in his summary of the Annual Meeting papers, dealt particularly with the subjects of engine vibration, body manufacture and the reduction of engine wear by the reduction of crankcase-oil dilution and the elimination of dust by air-cleaners. Additional interest was given to his address by lantern slides and apparatus loaned by speakers at the Detroit meeting. C. E. Summers, of the General Motors Research Corporation, sent the rubber crankshaft used to demonstrate bending stresses and crankshaft vibration. F. F. Chandler, of the Ross Gear & Tool Co., sent lantern slides of his new hydraulic steering-stress recording device, and T. S. Sligh, Jr., of the Bureau of Standards, sent his apparatus for determining the quantity of diluent present in used crankcase-oil, which was demonstrated by Mr. Younger at the Philadelphia gathering.

In the discussion following the talk, considerable interest was shown in the subjects of wheel shimmying, body manufacture and the oil-diluent experiment, and some questions were asked regarding the steering-stress recording apparatus.

PSYCHOLOGY OF AUTOMOBILE DRIVING

Reaction Time and the Personal Equation Engage Metropolitan Section

Does the prevention of accidents when driving automobiles depend upon the degree of concentration of the driver and the rapidity of his mental response to a stimulus or is the blame to be laid at the door, or rather at the tires and brakes, of the automobile, for failure to supply sufficient retardation? In other words, is it a matter of the personal equation of the driver or of the maximum possible deceleration of the automobile? These questions were discussed in two papers by the same author, H. H. Allen, of the Bureau of Standards, in collaboration with Dr. F. A. Moss, that were presented before the monthly meeting of the Metropolitan Section, held at the Hotel Empire, New York City, on Feb. 18.

Two revolvers mounted securely on the under side of the running board of an automobile and discharging shells loaded with red lead upon the road were the principal feature of the apparatus employed in making a series of tests upon three groups of individuals of assorted color, sex, age, education and experience in driving automobiles. One of these revolvers was fired by the experimenter when the car had reached a predetermined speed, as measured accurately by a chronometric tachometer, and the second, by the driver of the car in placing his foot on the brake-pedal. The ratio of the distance between the bright red spots produced on the road, measured in feet, to the speed of the car, in feet per second, gave the reaction time of the driver.

The three groups of individuals tested comprised (a) 36 students from George Washington University, including 10 female students; (b) 11 colored students from Howard University and (c) 10 taxicab drivers from the Black & White Taxicab Co., of the City of Washington. Each of the 57 drivers made runs at speeds of 10, 15, 20, 25 and 29½ m.p.h., respectively, so that the reaction times were computed from a total of 285 runs. The average reaction time for the entire series was found to be 0.54 sec. This corresponds to a distance of 22 ft. that the car will have covered when traveling at a speed of 30 m.p.h. before the driver begins to apply the brakes. The reaction times varied from the minimum, 0.31 sec., to the maximum, 1.02 sec. A measure of the variability of each driver was obtained by subtracting his shortest reaction time from the longest and dividing the result by two.

CONCLUSIONS

The general conclusions reached as a result of the tests were as follows:

(1) The average reaction time of the individuals tested was approximately 0.5 sec.

(2) A marked relation was found between an individual's reaction time and his mean variability

(3) The reaction time is not appreciably affected by the speed at which the car is driven

(4) The reaction time may be reduced by training; the reduction in some cases, however, must of necessity stop far short of that in others

(5) Little relation is apparent between the reaction time and the age of the individual
(6) The factor of sex shows little effect upon the reaction time
(7) Insufficient data are at hand to determine the effect of race on reaction time
(8) A marked relation was found between general intelligence and reaction time

Mathematics of Deceleration

Attention was then turned to a mathematical analysis of the limitations of the maximum possible deceleration obtainable under certain conditions, with a view to answering legal questions that might arise in case of accident, such as: (*a*) knowing the speed of the car prior to the application of the brakes, what is the minimum distance in which the car can be stopped? (*b*) knowing the distance in which a car has been stopped, what was its probable speed when the brakes were applied? and (*c*) knowing the speed and the stopping distance, what is the probability that the braking equipment was in good condition and was employed to the full extent of the operator's ability?

Limitations of space prevent the following of the author's reasoning in arriving at his conclusions. These, however, are (*a*) that the maximum deceleration in every case is independent of the weight of the car and is proportional to some extent to the coefficient of friction between the tire and the road; (*b*) that, in cars having two-wheel brakes only, the maximum deceleration increases as the percentage of weight on the rear wheels increases, as the height of the center of gravity of the car above the road becomes less and as the wheelbase becomes longer; (*c*) that the rate of change of deceleration with respect to the ratio of the height of the center of gravity above the road to the length of wheelbase is as the square of the rate of deceleration and in the opposite direction.

High Spots of the Discussion

In opening the discussion, A. J. Snow, in a written communication read by Secretary F. H. Dutcher, stated his belief that normal reaction time, as a basis for determining ability to guide an automobile safely, is open to criticism and that, although reaction time is one factor in the neurological make-up of a human being, reaction time under normal conditions is no index to the reaction time of a person under the emotional strain that is so obviously a factor in emergencies. After a study of about 10,000 cases, a series of tests had been developed by the Yellow Cab Co. that have been effective in reducing the number of accidents by 34 per cent.

H. M. Crane, in a written communication also read by Mr. Dutcher, called attention to the fact that what is called reaction time in the paper includes not only the mental reaction, but also a definite physical action, in response to the stimulus, that necessitated the moving of the driver's foot from the accelerator pedal to the brake-pedal before the second pistol could be fired. Practice, he said, tends to make this particular movement quicker and more certain. It is also probably affected by the relative position of the two pedals. The shorter reaction time of experienced drivers comes largely from practice in thus shifting the foot. In this series of tests, the drivers were all expecting to be asked to stop and were definitely thinking of stopping. Many accidents, he believed, were caused by drivers that drive without thinking of stopping. The emergency that arises when a driver is accelerating a car is likely to be more serious than one that arises when he is slowing-down, or preparing to slow-down. Tests might also be worked out to determine the relative reaction times on vehicles having unhandy pedal arrangements as compared with those having convenient relations to each other.

Laboratory Conditions

The reaction time represented by a stopping-distance of 22 ft., said Dr. A. T. Poffenberger, is extremely conservative. It is based on a sound stimulus, which gives the fastest type of reaction. Under laboratory conditions, a visual stimulus gives a reaction time about one-third longer. The conditions of the test also approached the ideal, for the person tested was in a fairly good state of preparation. In the laboratory the reaction time varies greatly with the state of preparation. Variation in a single individual may be as great as or greater than it is in the group. It may vary from 0.15 to 0.75 sec., which is a greater difference than the variation between a slow and a fast person.

The important thing, he believed, is to determine what are the factors that cause the individual to be unprepared to act. The situation is serious if the minimum stopping-distance is 22 ft. under the best conditions and will be increased because of the driver's state of mind, whether this is due to fatigue, inexperience, or other reasons. In the laboratory, variability is only about 10 per cent, but is greater the slower the individual.

Too much reliance should not be placed on ability to select a speedily reacting person because of his intelligence. This relation is not close. The chances are about one in six that the most intelligent person in a group will also be the fastest. A person may be too intelligent to be a good driver, that is, he may have so many other things on his mind that he will be unprepared to stop if an emergency should arise.

Chairman A. F. Masury corroborated this statement by referring to a series of tests made several years ago by his company. In these tests the slowest driver was a man who had been driving a truck for more than 15 years, but during that time had never had an accident. Other drivers with much greater intelligence had had many accidents.

Maximum Lane Capacity

In some tests made to determine the maximum lane capacity of various roads, said H. H. Hemmings, the average reaction time of drivers was found to be 0.49 sec. The lane capacity of Fifth Avenue was found to be about 800 cars per hr. per lane.

Many accidents, said R. E. Fielder, are caused by inattention and by failure of others to observe the rules of the road. In picking drivers, special care should be given to their natural bent and to their courtesy, that is, to determining whether the driver will give the right-of-way to a man who is entitled to it or will take a chance and jeopardize the equipment and the lives of persons on the highway.

Establishing in the individual the maximum preparedness, added Dr. Poffenberger, is what determines the speed at which he will be able to react, and is more important than fast reaction time. Fear of punishment is effective in producing a state of preparedness and in decreasing reaction time. Tests at Columbia University showed that the reaction time with a sound stimulus, normally 0.15 sec. under laboratory conditions, could be shortened, if fear of receiving an electric shock, after 0.15 sec. had elapsed, were introduced.

Although he had driven an automobile for 16 years, Dr. Poffenberger said that he carried no liability insurance because he believed that the responsibility for accidents should be his rather than the insurance company's. If persons felt that they must pay the price for killing a man or a child and could not pass the responsibility to an insurance company, fewer fatalities would occur. He cited the case of a wealthy friend who carried no insurance on his house because he considered the cost of replacing the house in case of fire to be of no consequence. He carried liability insurance, however, because he did not wish to be bothered with the complications that might arise from accidents while driving a car. Dr. Poffenberger believed that minimum reaction time is important but only as a "weeder out" of those totally unfit to drive cars.

Limits of Stopping-Distance

Inasmuch as the object of the discussion was to determine the advisability of setting a limit within which a driver must stop his car, H. W. Slauson suggested that this ability should be the deciding factor, when the driver's state of preparedness, the condition of the highway, the brakes and other factors are taken into account, and that, if he cannot

stop within a prescribed limit, when he is given some unexpected signal to do so, such, for instance, as a policeman's whistle, he is violating the law, because he is driving dangerously. Definite stopping-distances of this kind, suggested Mr. Slauson, might be set within certain zones of the city, in the same manner that speed laws are applied now.

In plotting the curves of some brake tests many years ago, remarked P. M. Heldt, the results indicated that the drivers had applied the brakes about 8 ft. in advance of the point at which they should have applied them.

A similar instance was cited by Mr. Allen in some recent compulsory tests taken by a friend in a suburb of New York City. It was practically impossible, he said, to stop within the prescribed distance when traveling at the required speed. In the first test, the driver overran the course. In the second test, by slackening the speed imperceptibly, throwing off the accelerator before reaching the line, and putting on the brakes sooner, he stopped about half-way between the marks. Comment was made to the effect that his brakes were "marvelous."

THE BRAINS OF PRODUCTION

Fundamental Ideas of Pre-Planning Production Presented to Detroit Section

Dividing the functions of the so-called "production brain" into cooperation and coordination, both conscious fundamental ideas without which no line of human endeavor can be prosecuted to a successful conclusion, and subdividing these into parts such as purchasing, planning, sales, maintenance and the like, Prof. Charles B. Gordy, of the University of Chicago, went on to show in his paper on The Brains of Production, presented at the production meeting of the Detroit Section held on Feb. 19, how a "planning department" utilizes these components in the interests of production. Regarding the part that management should play in eliminating inefficiencies of operation, he said that attention had been focused thereon by the application within recent years of scientific principles to the problems of management, and that this has been intensified more recently by a statement in the Hoover report on Waste In Industry to the effect that management can reasonably be charged with 50 per cent of all waste.

The elements involved in the problem of operating a production plant are under the control of its management, and not under the control of its workmen. Therefore, the burden of responsibility for devising the best ways and means of operation falls upon management. Among these elements are: The raw material used for production, its quality and the regularity of its supply; the equipment for working this raw material; the condition in which the equipment is maintained; the processes through which the raw material must pass to be converted into the finished product; the sequence in which parts are sent into the factory; and the working conditions under which the operatives must perform their tasks.

Production has developed to such a stage that efficient operation depends very definitely upon a pre-planning of all work and upon efficient selection and use of equipment. Two factors, quantity and standardization, have simplified some aspects of pre-planning, but they have complicated other components to some extent. Effective use of the equipment depends upon maintaining it in perfect operating condition, a proper adjustment of machines as to speeds, feeds and auxiliary equipment, and a determination of the best operating methods.

Professor Gordy believes, since layout, or the study of the effective arrangement of the machinery, affects the functioning of the planning department so vitally, that this department should have jurisdiction and should study the subject continuously. Such pre-planning consists of:

(1) Determining the number of completed products to be turned out during a given period
(2) Purchasing raw and semi-finished material to meet this schedule
(3) Developing a procedure for serving material to the manufacturing floors
(4) Ascertaining schedule quotas for each productive line and for each department
(5) Establishing a control element, one capable of directing these other elements

SCHEDULE OF SECTIONS MEETINGS

MARCH

4—Milwaukee Section—Standardization of Frames—L. C. Schwab
New England Section (Boston)—Flat Rate Symposium—R. T. Pierce, P. U. Holloway and Frederick P. Rudolph
5—Detroit Section—The Automotive Airbrake—H. D. Hukill; The Vacuum Brake—V. W. Kliesrath
6—Washington Section—Measurement of Crankcase-Oil Dilution—S. W. Sparrow and T. S. Sligh, Jr.
10—Pennsylvania Section—Building of All Steel Vehicle Bodies—Walter A. Graf
11—Dayton Section—Development of Supercharging and Its Effect on Engine Design—E. T. Jones
12—Indiana Section—Developments in Transmission—Demonstration in the afternoon of new and different types of transmission and general discussion in the evening
16—Cleveland Section—Road and Riding Ability—H. L. Horning
17—Buffalo Section—The Automotive Airbrake—H. D. Hukill
19—Detroit Section—Castings in Permanent Molds—Marc Stern and D. H. Meloche
Metropolitan Section—Automotive Distributing—Ray Sherman
20—Chicago Section—Recent Progress in Various Fields of Automotive Engineering—H. L. Horning, John S. Erskine and M. E. Chandler
26—Minneapolis Section—Automotive Rail-Car Engineering—S. E. Brennan and various railroad men of the Twin Cities
San Francisco Group—Effects of Engine Operation on Lubricating Oils—L. Wagner
27—Los Angeles Group——Efficiency of Air-Cleaning Devices—Prof. A. H. Hoffman

APRIL

7—Buffalo Section—Transportation Meeting
9—Indiana Section—Electrical Instruments for Automotive Research—J. H. Hunt

In an automobile plant, the planning department should control what equipment is to be used, the method of handling this equipment, the sequence of operations, the control of stores, the handling of material in the factory and the line required for producing parts of the products. The quota for the production line is based upon the foregoing controls, and a necessary preliminary to factory operations is the determination of the number of units of product that are to be produced. The specific duties within the jurisdiction of a planning department vary with the character of organization and with its personnel. However, its adequate functioning is dependent upon close coordination with the other departments in the plant, and this is particularly true in regard to purchasing. The maintenance department enables the planning department to rely upon the proper performance of the equipment; the inspection department, although a separate one, greatly facilitates planning-department work.

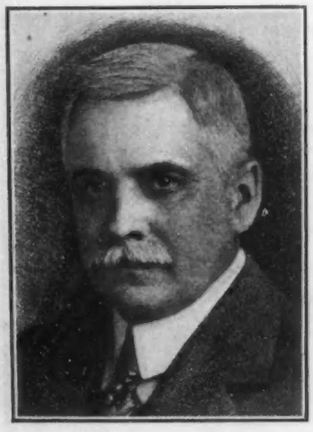
In the discussion following the paper, K. L. Herrmann, of the Studebaker Corporation of America, outlined the production planning methods of his company after its engineering department releases the blue prints and specifications necessary for the production of a new model of car; and R. S. Perry, of the Hudson Motor Car Co., elaborated some points relating to its practice regarding sales planning. Systematic handling of machine repair, a subject suggested by R. G. Waldron, was discussed also in some detail, and Professor Gordy replied to numerous queries relating to methods of production-planning procedure.

THE AIR MAIL SERVICE

Operation and Probable Future Development Discussed Before Chicago Section

Interesting details connected with the actual work of the Air Mail Service were presented before the Chicago Section at the meeting held on Feb. 20, at the rooms of the Western Society of Engineers, following a dinner at the Chicago Engineers' Club. The Association of Commerce cooperated with the Chicago Section, and a large and enthusiastic audience greeted the speaker of the evening, Col. Paul Henderson, second assistant postmaster-general in charge of Air Mail Service. The meeting was conducted under the chairmanship of Bion J. Arnold, president of the Arnold Co., a member of the Society, who is chairman of the Board of Supervising Engineers of Chicago Traction and also chairman of the Chicago Air Board.

Colonel Henderson first discussed some of the details of construction of the air-mail route, the equipment used in carrying the mail, the lighting of the routes and landing fields. He also showed a very interesting series of motion pictures which told the story of the air mail from the time it leaves New York City until it reaches its destination on the Pacific coast with deliveries at a number of important stations on the way.



BION J. ARNOLD

PAUL HENDERSON

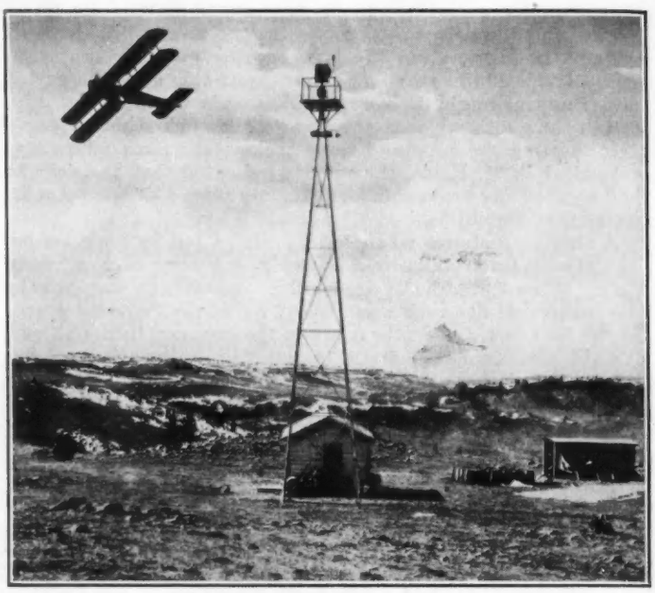


FIG. 1—THE HIGHEST BEACON LIGHT IN THE WORLD
This 5,000,000-Cp. Beacon Is Located at an Elevation of 8600 Ft. above Sea Level on the Top of Sherman Hill in the Rocky Mountains between Cheyenne and Laramie, Wyo. It Is Used To Guide Air Mail Pilots on Their Night Flights on the Transcontinental Route and in Good Weather Is Visible for 75 Miles

NIGHT FLYING

One of the most interesting features of Colonel Henderson's talk related to the equipment for illuminating the airways. At the present time the route from Chicago to Cheyenne is illuminated and is used for night flying. It is obviously necessary for provision to be made to allow the airplanes to operate after dark, for, unless the possibility of flying at night is guaranteed by effective illumination, the more rapid service by airplane will be curtailed.

The first experiment with a view to providing satisfactory landmarks to guide the pilot involved flood lighting of water tanks elevated above the ground and painted white. These could be seen 10 to 20 miles if they were properly illuminated.

Experiments were then made with the searchlight. Two types of searchlight are in use, a large type and a smaller one. The larger type is 36 in. in diameter and throws a beam of 500,000,000 cp. The light is mounted on a tower 60 ft. high and it rotates 16 times per min. The beam from this light may be seen in good weather conditions about 150 miles; under fair weather conditions, about 75 miles. An arc lamp is used. The smaller type of light, shown in Fig. 1, 18 in. in diameter, revolves 10 times per min. and casts a 5,000,000-cp. beam. The light may be seen in good weather at a distance of 75 miles; in fair weather, at a distance of 25 miles. An incandescent lamp is used.

Along the night section of the air-mail route, lights of the smaller type are stationed every 25 miles at each of 34 emergency landing fields. Lights of the larger type, at each of the five main landing fields, on the lighted airway between Chicago and Cheyenne, are approximately 250 miles apart. In addition to this equipment, lights of smaller power are placed every 3 miles along the route; these are automatic and are supplied by acetylene gas. One of these is illustrated in Fig. 2. The fields are properly illuminated for landing.

Relative to the efficiency of the Air Mail Service, Colonel Henderson mentioned a 4-day test that was conducted about a year and a half ago, as a result of which it was found that the trip from New York City to the Pacific coast could be made in 26 hr. and 14 min. The mail schedule, however, allows for a few hours more. By rail, the trip requires 91 hr.

Transcontinental Schedule

In the daily coast-to-coast service, inaugurated on July 1, 1924, the planes leave New York City at 10:00 a. m. and arrive at San Francisco the next afternoon at 4:50. They leave San Francisco at 6:00 a. m. on a given day and arrive in New York City at 5:00 p. m. the following day. The mails travel according to schedule at least 85 per cent of the time regardless of weather conditions; this record is being improved daily.

The Air Mail Service has recently extended the night-flying section from Chicago to Cleveland, and the material is now available for extending the next route from Cleveland to New York City. Plans are under way for establishing a service from Chicago to New York City that will be independent of the transcontinental service. With this in use, a person can mail a letter in New York City after the close of work on a given day, and it will be on the desk of the addressee the next morning when he appears for duty.

Colonel Henderson stated that the Air Mail Service should be considered not only as a great advantage in the transportation of mail with the minimum of delay, but also as an aeronautical experiment of gigantic scope. Much useful information has been obtained by this service, and it is certain that much more will be obtained in the future.

It was indicated that aircraft would be an important factor in a future war and that in such an event an efficient air service and a healthy airplane industry would be needed. It was pointed out that an adequate corps of efficient and well-trained pilots could turn from the Air Mail Service or from commercial aeronautics to war activities in case of emergency.

Fig. 2—One of the Routing Beacons

These Acetylene Gas Lights Are Spaced at 3-Mile Intervals on the Portion of the Transcontinental Air-Mail Route That Is Covered at Night. The Range of Visibility of These Lights, Which Flash 150 Times per Min., Is 10 Miles. The Sun Valve That Controls the Lighting and Extinguishing of the Light as Day-Light Falls at Night and Returns in the Morning Can Be Seen to the Left and Slightly below the Beacon

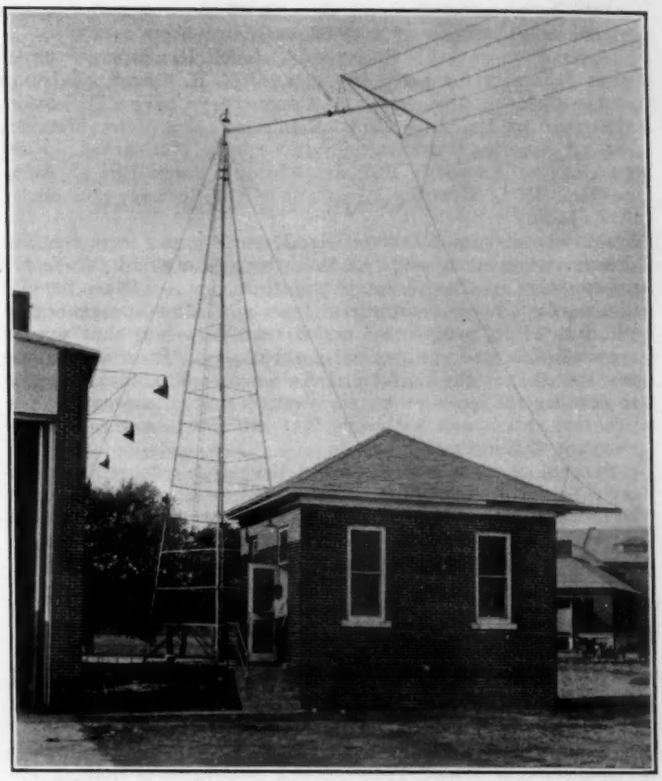


Fig. 3—Radio Plays an Important Part in the Air Mail Service

One of the Uses to Which It Will Be Put in the Near Future Is in Connection with an Instrument That Will Utilize Radio-Directed Waves To Show the Pilot the Proper Route To Follow

Colonel Henderson stated that the Air Mail Service will soon be ready in all probability to let contracts with private organizations for carrying the mails by air.

New Devices Tested

Many kinds of equipment and devices for air navigation have been tested on the air-mail routes. Others are to be tested in a new experimental route, 150 miles along, at right angles to the air mail, that is soon to be opened up. Among the devices to be tested is a radio altimeter, which is a radio broadcaster from an airplane that will tell the pilot his distance from the ground, by the time interval required for the wave to reach the ground and be reflected back to the plane. Another device is an earth-inductor compass supplanting the ordinary magnetic compass which fails in use in aircraft. An instrument is being developed that will use radio-directed waves to show the pilot the route that he should follow, and still other devices will be tested that are designed to make possible air navigation when the ground is not in sight. Clouds and bad weather present the greatest difficulties with which an air-mail pilot has to contend. The development of suitable instruments and devices is thus of paramount importance.

Colonel Henderson stated that within a year there will be in operation, over four or five main routes, an air mail service to Alaska. Satisfactory tests have already been completed.

Interesting facts brought out in the discussion of Colonel Henderson's talk included remarks relative of the financial savings that are possible through the use of the air mail. Bankers have found the Air Mail Service invaluable in conveying credit information that they hesitate to send by telegram. The usefulness of the Air Mail Service in this transportation of signatures and negotiable papers is obvious. The importance of the time element in interest-bearing paper is appreciated by bankers who have estimated that it

would be possible, through the use of the air mail, to save in the neighborhood of $450,000 a year in interest.

Among those who discussed Colonel Henderson's paper were Postmaster Lueder of Chicago; G. B. Foster, chairman of the Chicago Association of Commerce; Charles Dickinson, chairman of the Aero Club of Illinois; Mrs. John Metzger, one of America's women pilots; Captain McCracken, chairman of the American Bar Association's Committee on Aeronautics; H. L. Horning, president of the Society; and Major J. B. Lent.

All who discussed Colonel Henderson's paper were tremendously enthusiastic and felt that there is a great future for aeronautics in this Country and that the Air Mail Service can perhaps be more powerful than any other one agency to put into effect systems of aerial transportation that are at once efficient and commercially successful. President Horning stated that the Society of Automotive Engineers intends to further the question of aeronautics and to promote to the greatest extent any activities that promise to assist in aeronautical development.

Several of those who discussed the paper referred particularly to the skill, daring, courage and devotion to duty that have been exemplified by the pilots who have carried the mails under all sorts of weather conditions and through trying circumstances in general.

AIR, LAND AND WATER ENGINES

Buffalo Section Hears L. M. Woolson Compare Features of the Different Types

In general neither an automobile engine nor an aircraft engine can be transformed into a satisfactory marine engine without important revision in the basic design. The installation requirements as well as the conditions of operation of the different types make necessary the application of individual design factors. With these thoughts L. M. Woolson, aeronautical research engineer, Packard Motor Car Co., introduced his address on Modern High-Speed Marine Engines before the Feb. 17 meeting of the Buffalo Section.

In contrast with the automobile and airplane engines the marine type is usually installed in an *inclined position* in line with the propeller-shaft, the angle of which is determined by the lines of the hull, the fly-wheel size and other considerations. Clearances among other factors alter the design of the types for differing service.

As for running conditions, the automobile engine, during fully 75 per cent of its operating time, develops only about 25 per cent of its maximum output at perhaps one-third its maximum speed, whereas the marine engine is operated almost continually under at least 75 per cent full load. From the fact that good automobile engines are as capable of withstanding wide-open throttle service as are comparable marine engines, it does not follow that the automobile engine would operate with equal satisfaction in a boat developing the same output as the car.

Marine Engines Described

Mr. Woolson explained the details of the water-cooling system on Packard marine engines. It is arranged so as to eliminate the difficulties of over-cooling often encountered in marine installations. The system consists of the conventional marine circulating system with the addition of a thermostat and by-pass return line to the pump inlet. This by-pass is controlled by a so-called pressure-valve, that is, a spring-loaded check valve. In operation a small quantity of water is circulated through the system and the temperature rises rapidly until the thermostat opens and discharges hot water, thus allowing the pressure-valve to seat and cold water to be drawn in by the pump.

In the marine engines described by Mr. Woolson, spur-gear drives to the camshaft and accessory shaft are used instead of a silent chain. The principal reason for this was said to lie in the fact that the gear train is most conveniently mounted at the after end of the marine engine, whereas a chain drive at this end of the engine would be very inaccessible in case an examination of the chain should become desirable. The nature of the installation in a boat is such as to damp out noise from the timing-gears, whereas in a car these gears, if used even at the flywheel end, would result in the noise of the gears being multiplied by the drumming effect caused by the car structure at this point.

On marine engines such as those described, the simpler load requirements were said to be very well met by the use of the plain-tube type of carbureter.

A marine engine corresponding to the Shenandoah type of airship engine was discussed in detail. It has six individual steel cylinders of 6⅝-in. bore and 7½-in stroke, each cylinder having four valves operated by push rods and overhead rocker-arms. The marine type, unlike the airship type, is equipped with twin electric starters. The weight of electric starters prohibits their use in the aircraft engine. The marine engine has a compression ratio of 4¾ to 1.

Among the interesting features described by the speaker were the methods of lubricating the various parts and cooling by oil circulation. The latter extends to the exhaust-valves which are constructed so that cooling is effected by circulating the oil through the stems.

The valve springs are of the multiple cluster type and are arranged for each cylinder in planetary fashion around the valve-stem. From 7 to 10 of these springs made of small-diameter piano-wire are used with each valve. The advantage claimed for this divergence from conventional design is its greater dependability. In high-speed engines considerable trouble has been experienced from spring breakage, ofttimes with disastrous results. With the multiple arrangement the valve will continue to operate even though one or more of the individual springs may break.

Bearing Design

Mr. Woolson spoke of the bearing failures that have been caused in the past by fatigue of babbitt linings brought about by minute flexing of the bearing backing. By extensive tests it was determined that with proper precautions to insure that no flexing takes place the *PV* values for a bearing may be carried much higher than has heretofore been the practice.

Mr. Woolson concluded his address with a query as to why the power demands for high-speed boats are so far in excess of similar requirements for travel over land or through the air. It did not appear to him that the art of hull design has progressed as rapidly as has that applying to airplane design. In a plea for improved hull design he expressed the conviction that since the laws of fluid friction apply equally well to air and water, and since water and air propellers function with similar efficiencies, it should follow that for any given conditions of load and speed the power requirements should ultimately be approximately the same in both cases.

The discussion that followed Mr. Woolson's address served to bring out more clearly several of the details of designs that had been described. Among those who participated in the discussion were: O. M. Burkhardt, J. W. White, L. H. Pomeroy and E. T. Larkin.

MEETINGS OF THE LOS ANGELES GROUP

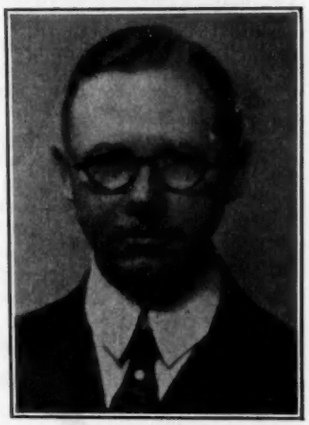
Cost of Operation and the Economic Life of a Motor Truck was the subject for presentation and discussion at the meeting of the members residing in or near Los Angeles held on Feb. 27 at the Elite Restaurant in that city. Three representative speakers, Joseph Scott, of the Bureau of Power & Light, City of Los Angeles; Eugene Power, superintendent of automotive equipment of the Union Oil Co.; and W. F. Fairbanks, superintendent of shops and vehicles for the Southern California Telephone Co., presented papers and prominent members of the automotive industry submitted written discussions.

Prof. A. H. Hoffman, of the University of California, will be the speaker at the next meeting of this group, which is scheduled for March 27. He expects to present his paper entitled Efficiency of Air-Cleaning Devices, thus giving the

engineers of this locality an opportunity to obtain at first hand and to discuss the data on this subject that have been presented at the Annual Meeting of the Society in Detroit in January and the February meeting of the San Francisco group.

HOW PASSENGER CARS CAN BE IMPROVED

Herbert Chase Suggests Desirable Changes to New England Section



HERBERT CHASE

Modern passenger-cars are far from attaining even to that degree of approximate perfection with which they are likely to be credited by a casual observer, and it is not at all unlikely that the next decade will see developments fully as important as and perhaps more radical than those that have taken place within the last 10 years.

With this as his thesis, Herbert Chase, in a paper read before the New England Section at a meeting held at the Engineers' Club, Boston, on Feb. 4, outlined a few specifications that he believed should occupy the attention of passenger-car designers in the future, the basic idea being the ultimate production of a car of relatively light weight that will be capable of averaging fully 30 miles per gal. of fuel and will have a reasonably high maximum speed, good accelerating ability and such other characteristics as would ensure good handling in traffic and easy parking. In his opinion, such a car, if properly developed prior to being placed on the market, would make an instant appeal to users and have a ready sale, provided the complete vehicle were attractive in appearance, reasonable in price, and of assured durability and dependability.

SUGGESTED IMPROVEMENTS

Among the possible improvements suggested were the following:

Engine.—Capable of giving high torque at comparatively low speed and having considerably higher economy at low loads than now is common

Transmission.—A gearless or continuous-torque type infinitely and automatically variable

Axles.—Much lighter than present types; possibly being replaced by flexible members that form a part of the suspension system

Frame.—Considerably lighter than the conventional type; being incorporated, possibly, as a structural element of the body

Brakes.—Effective and long-wearing without squeaks; probably fitted on all wheels, at least in the case of large cars

Tires.—Affording the maximum riding-comfort when mounted on rims that allow them to be easily detached, preferably without tools

Body.—Lightweight noiseless enclosed type, with comfortable adjustable removable seats having back rests that move up and down with the passenger; well ventilated yet weather-tight and fitted with a heater for use in winter; finished inside and outside with durable material that is easily kept clean

Suspension.—Giving the maximum riding-comfort with freedom from squeaks, rattles and vibration

Steering-System.—Safe and easy to operate and free from influences that tend to produce wheel-wabble and the resultant shimmying

Cooling System.—Capable of becoming warm quickly and of maintaining a reasonably high and approximately uniform temperature of the entire engine

Lubrication.—A central system serving all wearing parts of the car and requiring to be filled not oftener than once per 1000 miles

Although many of these specifications may be considered radical, said Mr. Chase, practically all have proved worthwhile on experimental cars. Some are already in production while others are being given close study by progressive manufacturers. Because of the overproduction of cars, the makers are seeking additional selling features, inasmuch as improved manufacturing methods have decreased the cost of production to a point beyond which further reduction is not to be expected.

In elaborating these suggestions, Mr. Chase called attention to the anomaly of a vehicle's weighing from 4 to 10 times the passenger load that it is designed to carry. Economy, therefore, demands lighter weight; and the future will undoubtedly see the use of lighter vehicles, although the adoption in the Country of so diminutive cars as are popular in Europe is improbable.

LIGHT BODIES ESSENTIAL

Reduction of weight must begin with the body, for the weight of the frame, springs, running-gear, engine and transmission cannot be decreased greatly unless the weight that must be carried is lessened. As a step in this direction, the use of a light flexible body of the Weymann type, described at the Annual Meeting of the Society[1], was referred to. If comfortable seats for the passengers are supported by the chassis, the remaining portion of the body becomes nothing more than an enclosure for protecting passengers from the weather. Such requirements as being rattleproof, non-resonant, easy of access, well ventilated, durable and presenting an attractive appearance can be met without excessive weight. All-metal bodies, if the resonant effects can be overcome, possess certain advantages, especially with regard to the facility with which they can be adapted to quantity production.

Some motorbus bodies, continued Mr. Chase, have been reduced in weight by the omission of sills and bolsters and by the use of reed, twisted fiber or rattan seats, and of wood in certain parts. Because the body is usually considered to be a thing apart from the chassis, sills and bolsters have been viewed as essential, but if the chassis and the body can share a common frame or foundation, the weight can be reduced.

Plate glass is the source of considerable weight as well as danger. The discovery of a suitable substitute for it that would be less brittle, not easily scratched, equally transparent and of less weight would find wide application in body work, provided the cost were not excessive, and would bring a great reward to the producer.

With the reduction of the weight of the body would come a lighter chassis. The axles and springs would have to support less weight, a lighter engine would suffice to propel the vehicle, and the lower torque of such an engine would enable the use of lighter transmission units, clutch, gearset, propeller-shaft and live-axle parts.

Among the details of body construction that should receive attention, added Mr. Chase, are seats that should be adjustable and move with the passenger rather than wear his clothing by friction with the seat; windshields that should be easily adjustable from the seat while giving the maximum visibility and being capable of excluding rain and of shielding the driver from unnecessary glare from the sun and from the head-lamps of approaching cars, a well-designed visor that would keep the windshield clear during stormy weather and a heater capable of maintaining a desirable temperature and of supplying heat to the driver's feet.

[1] See THE JOURNAL, February, 1924, p. 215.

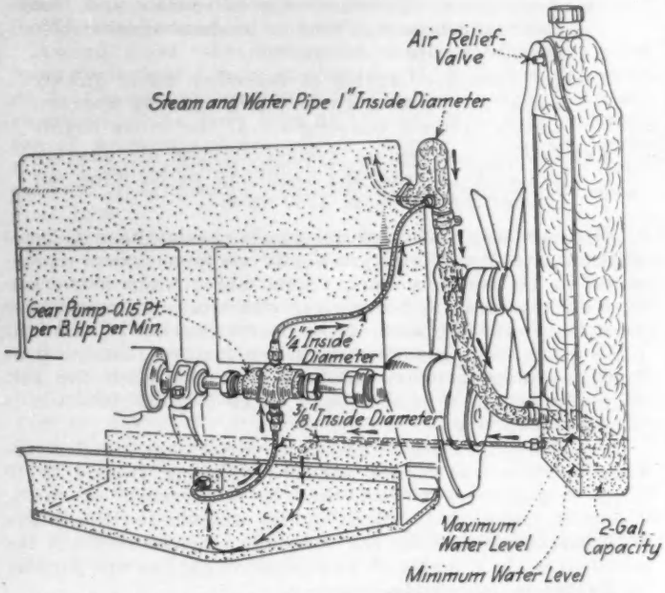


FIG. 1—DIAGRAM OF THE RUSHMORE STEAM COOLING SYSTEM
The Water in the Cylinder and the Oil-Pan Jackets and the Steam in the Outlet Pipe and the Radiator Core Are Clearly Shown. The Direction of Flow Is Indicated by Arrows

THE ENGINE

As requisites to an improved engine, were mentioned the need of greater economy of fuel at low loads, which is the average condition in normal service; higher torque at low speed; more nearly equal distribution of fuel; the overcoming of erratic functioning during the warming-up period and of the difficulty of starting in cold weather; more adequate lubrication during the starting period; a reduction of the rate of wear because of the inhalation of abrasive material; and the avoidance of noise and vibration.

Part-load fuel economy, Mr. Chase suggested, could be improved by eliminating the throttle, or by maintaining compression at all loads in some other way, through some form of localized charge in the combustion-chamber. Higher torque at low speed was said to be attainable through the use of the two-stroke-cycle type of engine, by which some engineers have obtained extraordinary results, a single-cylinder engine mounted on a chassis about the size of a Ford chassis having proved capable of traveling from 65 to 80 miles on a gallon of gasoline, without resort to coasting or other abnormal driving. Such engines are said to be highly efficient at part load, to give comparatively high torque at low speed, and to possess low friction losses.

Inequality of fuel distribution and the feeding of a richer charge to some cylinders than to others results in waste of fuel, a tendency to cause vibration, incomplete combustion and the consequent discharge of carbon monoxide. Attempted improvements in carbureter design have resulted in increasing the complication of the apparatus. If the amount of effort that has been devoted to curing the ills caused by poor distribution were directed toward securing positive distribution, most if not all, of these ills could probably be prevented. They include such things as crankcase-oil dilution and the difficulties of starting. Evaporative cooling-systems are asserted to give promise as a means of rapidly warming the engine.

PISTON AND CYLINDER WEAR

Rapid wear of the piston and of the cylinder, and sometimes scoring of the piston, results from a tardy supplying of lubricant to the cylinder-walls when the engine is started. This is owing to the low pressure's not being able to force the lubricant through the bearings quickly enough, so that the oil passes off through the pressure-relief valve instead. On some foreign cars no pressure-relief valve is provided; consequently a very high pressure is developed quickly and oil is forced through the bearing almost immediately.

With a view to preventing dilution of the engine oil by fuel that passes the pistons, said Mr. Chase, several devices are being used to distill off the fuel diluent and to filter other foreign matter out of the oil. These devices at present are necessary, but advantage would accrue to an engine in which they were not necessary. Dilution, however, can be lessened by these expedients, and filters and air-cleaners will help to prevent the entrance of abrasive matter. Better balancing, the use of stiffer structures and better distribution and lubrication will do much to reduce noise and vibration.

Although the present conventional gearset has proved simple, dependable and economical, it requires skill to make gear changes without noise, and the flow of power to the rear wheels is interrupted during the process. Continuous torque and an infinitely variable substitute for the gearset would overcome these disadvantages; but no such substitute has as yet appeared.

Alloy-steel tubular members of large diameter and thin wall are said to have been used to produce exceptionally light and stiff chassis frames, but no frames of this kind have as yet reached the manufacturing stage. In the Lancia car, the construction is of the so-called "frameless" type, the chassis frame being absent and all the mechanical units being attached to the body; but this car is not in wide use in this Country. This type of construction involves so radical departures from conventional design that few manufacturers would be inclined to consider them at the present time.

BRAKE-LININGS

Research work at the Bureau of Standards and among brake-lining manufacturers has increased the life of the linings materially. If they could be made not to screech and the braking torque could be equalized, braking systems would compare favorably in standard with other parts of the car. Brake-drums of high-carbon steel wear better than do those of low-carbon steel, and tend to reduce screeching. Hand-brakes have not been improved since they were first installed. They should include a durable ratchet having possibly a double pawl with staggered teeth.

The facility with which tires can be removed and replaced without the use of tools when drop-center rims are used has given these rims great popularity in England; provided no serious disadvantages develop, it is not unlikely that they may meet with equal favor in this Country.

Although present types of axle are satisfactory, their weight could be decreased if they were not obliged to carry so heavy bodies. A car in which the rigid axle was replaced by a transverse spring or springs, combined, in the case of the rear axle, with a sort of flexible driving mechanism, was said to possess exceptionally good riding-qualities. This construction, doubtless, would prove satisfactory on light cars but so far has not been attempted in a quantitative way. To allow the use of a very low frame, a motorbus manufacturer has produced several chassis using a front-wheel-drive mechanism in which a single heavy transverse spring and a pair of radius members take the place of the normal form of axle. In this chassis the trailing wheels are carried on radius-arms pivoted to the chassis frame; there is no rear axle, but a heavy transverse tubular member of the frame performs a structural function similar to that of the ordinary rear-axle housing. The unsprung weight is said to be lower than that of other chassis in similar service and the riding-qualities to be exceptionally good. Inasmuch as axle shocks are greatly reduced by the use of balloon tires, so heavy axle parts would not be necessary were it not that a certain rigidity is necessary to preserve the alignment of parts and to prevent flexing that might induce wheel-wabble and other difficulties. One or two designs of self-locking differential recently developed have advantages in soft and slippery going and should be adopted if they fulfil other requirements.

SPRING-SUSPENSION

There is need of types of spring-suspension, continued Mr. Chase, that will give equally good riding-qualities at light, medium and heavy loads, that will give freedom from squeaks and rattles and will insulate the passengers from annoying

vibration. These demands have been met in a way by non-metallic shackles, torque-arm supports and certain types of engine mounting; and their use will undoubtedly increase.

Believing that wheel-wabble and the consequent shimmying are caused, not primarily by the tire, but by certain features of design of the front axle, the steering-system and the springs, as a result of lost motion, lack of rigidity of the parts, unbalance and faulty layout of the drag-link, Mr. Chase favors an approximately vertical pivot in combination with a hub or wheel design that will give as nearly center-point steering as other conditions will allow.

Chassis lubrication is frequently neglected by car users, he added, because it is a dirty and disagreeable task. This personal element could be overcome if a single central filling-point were provided. Although such a system would entail additional piping, the advantages would be worth the sacrifice, if the expense were warranted. It might not be desirable to connect the engine and the chassis lubricating systems, but the same oil could be used for both and a common filler-pipe could be employed. Operation of such a system by a foot-plunger has proved satisfactory.

Although some of the improvements suggested may seem to be radical, concluded Mr. Chase, a car embodying these refinements would be far in advance of any on the market at the present time.

Points Brought Out in the Discussion

In reply to questions in the discussion that followed, Mr. Chase stated that, in his opinion, the supercharger as used on automobiles merely adds complication without materially increasing the efficiency, but that it is useful on racing cars. Describing the steam cooling-system, a view of which is shown in Fig. 1, he said that with it the same trouble is not experienced as is encountered in water cooling-systems. A positive pump should be used. As the system is closed, additional water need not be supplied for weeks at a time. The total amount of water is less than that in water cooling-systems, because the radiator is not filled. The same radiator can be used in both systems with slight modifications but, in general, a smaller radiator and a smaller fan are used in the steam cooling-system.

In the ideal car that was described in the paper, a view of which is shown in Fig. 2, the springs are made as flexible as possible and are supported in non-metallic construction. There is little vibration, the tires are easily detachable, the rims being the same as the old bicycle rims, the engine is small, the finish is good, the structure is of light weight, the seats can be easily removed and adjusted to the passenger, the differential is self-locking, the wind-shield can be regulated simply by turning a crank, and the seats are mounted on springs.

Trouble has been experienced with two-stroke engines in the past because they did not throttle well at low load. This, Mr. Chase said, could be avoided by putting the throttle on the exhaust and by preventing too rapid passage of the exhaust at part load.

So-called "frameless" cars are of foreign origin. The body does not have a real frame. It is made of metal and supports its own weight without a wooden frame. In the Marmon car, to which reference was made, the flange is carried down inside the frame but the frame is mounted much as in other cars.

Sleeve-Valve Engines

Sleeve-valve engines, Mr. Chase said, are used by the Yellow Coach Co., the Fifth Avenue Coach Co. and one other company, but most of the remaining ones use the poppet-valve type. The Maybach car has a single speed, with the engine large enough to start in high gear with no slipping of the clutch, and planetary transmission for starting on a grade.

Various attempts have been made to find a substitute for the gear-set. In the new motorbuses ordered for Philadelphia, a gasoline-electric drive has been adopted. In starting an engine, the thermo-siphon system in Mr. Chase's opinion has certain disadvantages, namely, the flow of water is erratic; a larger radiator is needed; the flow is likely to be intermittent unless the piping is very large; so high temperatures cannot be used as with the steam cooling-system and the rate of circulation is less. When steam forms, it seeks an exit at a rapid rate and, unless obstructed, goes quickly to the radiator. The temperature, consequently, is high, as compared with that of the water in the radiator, so that the size of the radiator in the steam cooling-system is considerably smaller than that of the thermo-siphon system.

DURABILITY OF NITRO-CELLULOSE

Its Qualities and Causes of Disintegration Entertain Indiana Section

The qualities and durability of nitro-cellulose finishes for automobiles occupied the spotlight at a meeting of the Indiana Section on Feb. 12., papers being read by H. C. Mougey, control chemist of the General Motors Research Corporation, and L. Valentine Pulsifer, chief chemist of Valentine & Co.

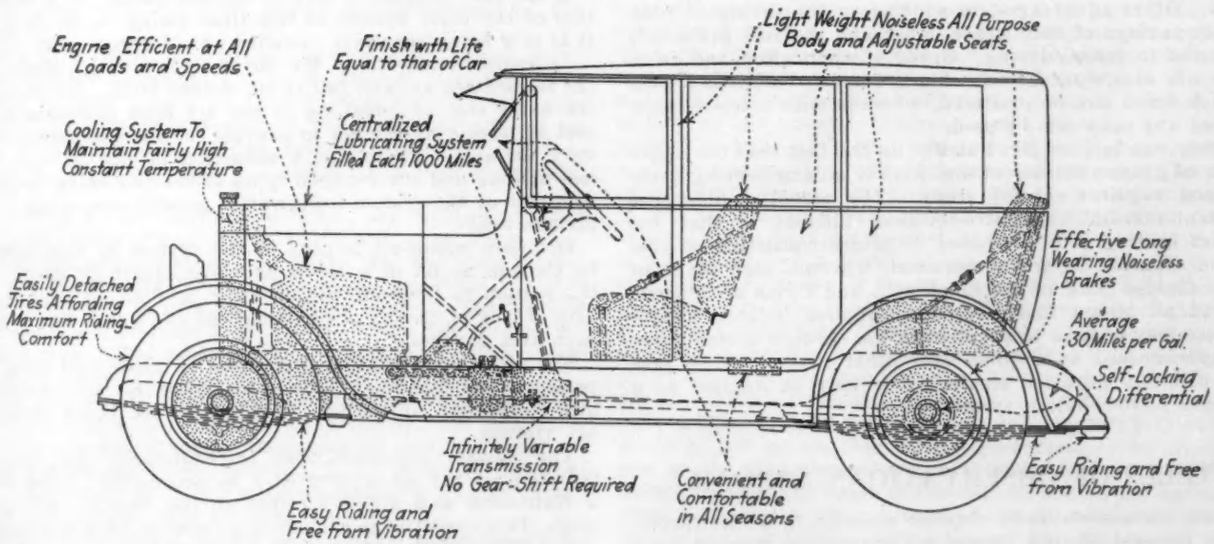

Engine Efficient at All Loads and Speeds
Finish with Life Equal to that of Car
Light Weight Noiseless All Purpose Body and Adjustable Seats
Cooling System To Maintain Fairly High Constant Temperature
Centralized Lubricating System Filled Each 1000 Miles
Effective Long Wearing Noiseless Brakes
Easily Detached Tires Affording Maximum Riding Comfort
Average 30 Miles per Gal.
Self-Locking Differential
Infinitely Variable Transmission No Gear-Shift Required
Convenient and Comfortable in All Seasons
Easy Riding and Free from Vibration
Easy Riding and Free from Vibration

FIG. 2—IMPROVEMENTS POSSIBLE IN CAR CONSTRUCTION
Some of the Various Changes Perhaps Are Radical, but a Car Embodying These Refinements Would Be Far in Advance of Any Vehicle Now on the Market

A satisfactory finishing system, said Mr. Mougey, must, at the least cost of labor, time and money, produce a finish that will stick to the automobile, have a smooth surface of the proper color, and be of the desired luster. It must also retain these properties for as long a time as possible. By drawings and photographs, the various stages of application and of disintegration of automobile finishes were followed and the causes of their failure were discussed.

Failure of ordinary automobile varnish is produced chiefly by the lack of durability of the color and rubbing coats, the primary causes being the effect upon them of the actinic rays of sunlight and heat. Consequently, as the number of hours of sunshine in July is about three times as great as in December, the summer season is the more destructive.

The finishing coat is easily scratched, continued Mr. Mougey, and disintegration begins at the scratches. They may be caused by dust, by cleaning or by mechanical injury. Continual polishing, even if only water is used, shortens the life of varnish, and so-called polishes, foods and seals, instead of increasing its life, cause the varnish film to fail prematurely.

Nitro-Cellulose Lengthens Life of Varnish

Inasmuch as the most vulnerable point of the varnish coating is the low durability of the color and rubbing coats, the life of varnish can be increased from two to four times by replacing these coats with nitro-cellulose material, which, when applied, dries quickly by the evaporation of the solvent, rather than by chemical change, leaving a hard, tough and durable film. When this was done, the finishing coat was then found to be the limiting factor, and the experiment was made of applying nitro-cellulose material directly over the primer and surfacer coats and polishing it.

Deterioration of the nitro-cellulose finish is produced by microscopic cracks in the surface due to change of temperature and moisture. These give the surface a chalky appearance but the original luster can be restored by mild washing or polishing, and this operation can be repeated many times before serious wearing will occur.

Experience in producing coatings for aircraft during the war, when speed of application was the essential requirement, had first directed his attention to what could be accomplished with nitro-cellulose finishes, said Mr. Pulsifer. But, at first, difficulty was found in getting the right balance of adhesion, lack of shrink, elasticity, plasticity, hardness, polish and durability.

Speed of Application

A nitro-cellulose process can now be applied complete in 48 hr. Other advantages, in addition to the saving of time, include savings of floor space, labor and the fuel previously consumed in forced drying. Speed of application and durability are also obtained with black enamel, but with it only a black finish can be produced, whereas with nitro-cellulose finishes any color can be used.

Stress was laid by Mr. Pulsifer on the fact that the application of proper finishes of any kind is an engineering problem and requires careful study. The essential difference between varnish and nitro-cellulose finishes is that the varnish coating is a laminated structure consisting of successive separate layers of material, whereas each layer of nitro-cellulose material combines with and forms an integral part of all others that have been applied before. Nitro-cellulose may be used to supplement the old-time system, may be superimposed as a finish over other undercoatings that have properly adjusted elasticity, or may be applied as a complete nitro-cellulose system.

TELLS OF OBSERVATIONS ABROAD

In his characteristically popular manner, C. F. Kettering, of the General Motors Research Corporation, related some of his experiences and observations in Europe and Northern Africa on his recent trip abroad, before a joint meeting of the Dayton Engineering Club and the Dayton Section of the Society in Dayton on Feb. 3. The primary purpose of the trip was to investigate the production of certain raw materials but Mr. Kettering also observed the trend of scientific research and the development of manufacturing processes in England, France, Germany and Italy. He stressed the importance of getting the right point of view, of having some fundamental idea of what we are trying to do along scientific and engineering lines and why we are doing it, and of not judging developments solely by our own experiences and the conditions under which we live. He described how the nitrate plants in Germany are fixing more nitrates from the nitrogen of the air and the hydrogen of water than are being produced in all the natural nitrate mines in the world, about 350,000 tons a year. He also told how in Europe the scientific research workers are studying the problem of developing foods by the action of sunlight upon organic compounds. He gave a running comment on conditions and production processes in various countries and related some amusing incidents of his trip to Tunisia.

CENTRAL CHASSIS-LUBRICATION

First Announcement of Bijur System Made at Detroit Section Meeting

J. Bijur

In presenting his paper at the Detroit Section meeting held on Feb. 5, Joseph Bijur referred to the previous chassis lubrication systems that had been introduced, such as the Ferguson, the Romon and the Bowen. The paper is printed in full elsewhere in this issue of The Journal. Mr. Bijur expressed the opinion that such a system is of as revolutionary a character as was the introduction many years ago of electric engine-starting systems on passenger cars. He said that the two major problems he had encountered in experimental work were breakage of pipes and the feeding of too little or too much oil, these being largely the result of crudeness of form of pipes and fittings.

Additional interest is lent to the publication of a description of the Bijur system at this time, owing to the fact that it is now being regularly installed on a leading make of car.

In answer to questions, Mr. Bijur made a rough guess that the lubricating system, full of oil, weighs 10 lb. He said that the extra cost of installing it has not been determined, the cost of modifying the car to provide for the equipment being very variable. There was a reduction in cost in one case; less drilling and lower-priced types of bearing being involved. The cost of the system itself varies greatly according to the fittings used.

Ordinary motor-oil is used in the system in this climate. In Canada an oil of a lower pour-test might be used. For the system to function, the oil must be fluid, of course. In case of lack of fluidity, a car should be run into a warm place such as a garage.

Mr. Bijur said that no breakage of pipes had been experienced; in fact, that there is no reason for such breakage any more than any other. The pipes, not being loose, do not vibrate.

The speaker continued with the statement that the distribution of the oil is very easy to accomplish, there being a restriction and a felt strainer in the lead to each drip-plug. It is essential to exclude solid matter from the system.

Mr. Bijur spoke of the system as a lazy man's device; it saves work on the car user's part.

The author stated that laboratory tests at a temperature of 20 deg. below zero fahr. had been made and that no

appreciable difference in the oiling could be detected in cold weather. He was of the opinion that some particular oils might function better than others, but that it would take a long time to ascertain the facts as to this. Good results had been attained over a period of years, there being no wear of bearing parts except that due to dust.

It was pointed out that if a line of the system is opened, no air can enter through the drip-plug or the actuating gun and therefore no oil flows. When the gun is actuated, oil will run out or leak slightly.

In answer to a query, Mr. Bijur said that no trouble had been had with the lines becoming clogged. The crux, the essential thing, of the system is the filtering of the oil, so that there will be no material in it to clog a bearing. If a nut is not tight at a given point, there will be merely a greater flow of oil than there should be.

When a section of a pipe line is replaced, a long air-bubble is introduced into the system. When the gun, which actuates the operation of the whole system, is operated, the air pressure rises less quickly in accordance with the volume of the air bubble. When, say, the air bubble is reduced to half its first size, the 15-lb. pressure exerted by the gun would probably not actuate the system but, upon using the gun again, the requisite 30-lb. pressure would be had, air escaping from the system with a slight hiss. Mr. Bijur said that no appreciable trouble had been experienced in cold weather, using a pressure of 55 lb.

One thing about which Mr. Bijur was questioned particularly was whether in cold weather more oil would run out a drip-plug near the pump than from a drip-plug at a greater distance. He replied that there is no such tendency. In cold weather the resistance in the system increases greatly at the end of a line, but also at the drip-plugs. Therefore, temperature has nothing to do with the operation of the system in this respect.

For a large car, 60 ft. of pipe is used for the oiling system.

As to how frequently the pump should be used, Mr. Bijur said that when using it once a day the amount of over-lubrication would be very slight in the case of ordinary driving. In such case the plunger of the pump could be pulled out only half its total stroke. Mr. Bijur is of the opinion that the best condition would be had when oiling every 200 miles. The determining thing in this connection is mileage. Practically, it is feasible to actuate the pump when turning on the ignition. Except when touring, few car-owners drive more than 100 miles a day.

Questioned as to the use of Oildag, Mr. Bijur expressed the opinion that it should be as good as any other oil if the graphite remains permanently suspended in the oil. Oil that contains solid particles that cannot be filtered out is objectionable.

The author said that in lubricating with grease more grease appears at openings than at bearing surfaces. Also that the central system of chassis lubrication is very economical of oil, using one-half or one-third as much oil as would be used with an oil-can system. The cost for oil is negligible. A quart of oil will suffice for 2 months, in hard driving.

According to Mr. Bijur's estimate, the methods of car lubrication generally in vogue today are very costly, considering labor charges and lost time. He felt that $100 a year is a reasonable figure under these conditions.

Varnished silk is used on the valve seats in the form of small selected discs free from flaws. White felt is used for the strainers. The tubes are of 3/16 or 5/32-in. diameter with ⅛-in. bore.

F. H. Gleason, of the Bowen Products Corporation, which produces a central chassis-lubrication system, said that, after use of the system in many thousands of cars, no report of tube breakage had been received. L. L. Williams said that he had driven a car 27,000 miles successfully without breakage of the flexible type of tube used.

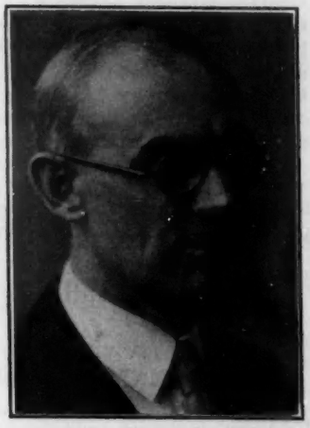
Mr. Bijur exhibited models in operation made up of the types of tube and other fittings he uses.

With regard to the difference of opinion as to the desirability of providing lubrication between leaves of springs, Mr. Bijur expressed preference for lubricating them.

Chairman Geo. L. McCain, of the Detroit Section, expressed the thanks of those present to Mr. Bijur for presenting the paper, which was comprehensive, yet remarkably concise.

CHARTING OF STEERING EFFECTS

Washington Section Has Methods Explained and Results Interpreted



F. F. CHANDLER

Conclusions based on analyses of charts relating to steering effects, obtained with instruments described in a previous paper, were presented by F. F. Chandler, chief engineer of the Ross Gear & Tool Co., Lafayette, Ind., at the meeting of the Washington Section held on Feb. 13 in the Cosmos Club lecture hall.

In addition to presenting the material contained in his previous paper on How Hard Does a Car Steer?[1] Mr. Chandler compared the steering effects produced by balloon and by high-pressure tires, and also discussed briefly the subject of wheel shimmy. He said that, when hitting obstacles with balloon tires, a drag-link stress of 175 lb. had been produced, at a given speed, as compared with a 140-lb. drag-link stress produced by high-pressure tires under similar conditions. He explained this unlooked for result by saying that, at the particular speed at which the car was traveling, a kind of compound effect exists. The tire is first indented by hitting the obstacle and, before the pressure due to the impact is through acting on the drag-link, the effort of the tire to react and become round again has increased the drag-link stress by a certain amount. He stated that the instruments show clearly the very much greater number of vibrations in the drag-link when high-pressure tires are used, in comparison with the vibrations that occur when balloon tires are used.

Mr. Chandler believes that, roughly, drag-link stress is inversely proportional to tire pressure. He stated that the drag-link stress may easily reach 25 times the stress present when the car is moving at 35 m.p.h. on a gravel road, in a case where the front wheels are cut and the car is standing still. It is known that the effort of driving is reduced materially as car speed is increased while touring, but he expressed surprise at finding this ratio to be as great as 25 to 1. Charts show that, with high-pressure tires, a driver may expend from two to two and one-half times as much effort in getting out of a flat-to-the-curb parking-position as he expends when backing in; that is, it is that amount harder to get out of such a position than to get into it. With balloon tire equipment, it is 40 per cent more difficult than with high-pressure tires, to get out of such a curb position. On gravel, right-hand turns made at the same speed are not appreciably harder for the average driver on a 25 lb. per sq. in. tire-pressure than when he is driving on say 50 lb. per sq. in. inflation-pressure. However, on pavement, the same turn is from 30 to 40 per cent more difficult with balloon tires at 25 lb. per sq. in. than with high-pressure tires at 50 lb. per sq. in. air-pressure, unquestionably due to the clinging effort of the larger tread of the balloon tire on the pavement, since the gravel offers a crude form of ball-bearing effect due to its composition of particles. The making of turns on pavement requires from 300 to 400 per cent more effort than that expended in making turns on gravel.

Cars are so radically different in steering performance

[1] See THE JOURNAL, February, 1925, p. 183.

that no one set of qualities in a steering-gear will give equally satisfactory results in all of them. For example, Mr. Chandler said that certain cars now on the market are devoid of "road sympathy," or the quality of the steering-system that enables one to "feel" the road as one drives, without conscious effort.

Regarding wheel shimmy, after trials of a certain car relative to steering and shimmy effects of which he gave details, Mr. Chandler concludes that, concerning the latter, a certain relationship or harmony exists between the number of vibrations the axle makes on account of the inflation-pressure and the number of vibrations the spring makes due to its natural spring-characteristics, and this was borne out by tests made later. He found also that shimmy can be eliminated in particular instances by raising the air-pressure in the tire, and that it can be killed by reducing the inflation-pressure excessively. He believes that, if the harmonic relationship which apparently exists between inflation-pressure and spring vibration is broken by increasing the inflation-pressure, by decreasing this pressure or by changing the periodicity of the spring, shimmy will be avoided.

Major subjects in the discussion that followed the paper included "road sympathy," "fast" and "slow" steering-systems, variable ratios of steering-wheel effort to drag-link pressure, "high" and "low-speed shimmy" and the like.

VOLTAGE-REGULATED SYSTEMS

Milwaukee Section Learns Uptodate Practice in Motorbus Applications

L. P. Michaud

Progress made in the development of electrical equipment to serve adequately the needs of motorbus service was reviewed comprehensively by A. A. Skinner, of the Leece-Neville Co., Cleveland, in his paper on Voltage Regulation, and by L. P. Michaud, of the North-East Electric Co., Rochester, N. Y., in his paper on Suitable Voltages for Motorbus Lighting, at the meeting of the Milwaukee Section held on Feb. 4. Mr. Skinner was first on the program, the more important subjects of his paper being presented in the following paragraphs.

Voltage regulation is the latest development in the electrical control of an automotive generating system. Of the many improvements in motor-coach equipment, the most interesting is the progress made in the generating systems to assure sufficient light to make these vehicles attractive at night.

Electrical loads on motor-coaches are comparatively high, including the usual head, tail and dash lamps, body-marking and destination lamps and buzzer systems. In some cases even greater loads are imposed by electric fans and electric heating systems. As more and more electrical energy is used, the source of supply and the control become more important, relatively. Not only does the electric generating system have to meet the demands of battery charging but it should be able to carry the connected load with no battery in the circuit. This means that not only is sufficient energy necessary, but the voltage must be regulated in such a manner that the battery can be charged without endangering the life of the lamps because of excess voltage. Further, the voltage of the lamps must be steady and there must be no perceptible flicker in the light. And all these results must be attained under conditions of variable load, variable speed and changeable temperatures encountered in service.

It is common practice in present automotive installations to use the familiar type of third-brush-controlled generator for supplying energy to the storage-battery and lights, as this type tends to maintain a fairly constant rate of battery charging-current at all times.

Voltage Regulation

Two divisions of the subject were made by Mr. Skinner; constant-voltage, and voltage-regulated systems. By "constant voltage," a practically unchanging terminal potential is meant, within close limits such as say 0.3 volt or less, under varying conditions of load, speed and wide extremes of temperature, such as may be met in the air. "Voltage regulation," as commonly applied, refers to a system that regulates within somewhat wider limits, such as those met on a motorbus or motor truck for battery and lighting service.

Regarding the charging characteristic of third-brush generators, on protracted charging, as the battery takes its charge and the voltage increases, the voltage of the generator tends to increase, keeping sufficiently above the battery voltage to force a fairly uniform amount of current through the battery. The value of the current is affected by the setting of the third brush; and this type has been termed "current-controlled," its chief characteristic being a fairly constant charging-rate regardless of battery conditions. But the tendency for the third-brush system in continuous service is to charge at too high a rate when the battery is well up in charge, and to furnish insufficient energy when the battery is in a discharged condition.

The voltage-regulated generator furnishes a controlled voltage for lamp lighting, and results in a tapering battery-charging rate. Its purpose is to furnish a regulated potential within the limits required to give steady, non-flickering, non-changing light and, at the same time to assure proper battery charging. Such systems are not "constant-potential" systems, in that the voltage is not held absolutely at one value but varies slightly within the limits required by the nature of the application.

Mr. Skinner referred to the limiting conditions that circumscribe the manufacturers, in regard to voltage-regulated equipment. For example, on a 12-volt system, the lamps should be operated at approximately 14½ volts to assure maximum life, and yet a potential of 15 volts and sometimes more is needed to charge the batteries used, and this necessitates a compromise generator-voltage. He then reviewed briefly the history of automotive electrical systems that led to the development of the voltage-regulated system.

Third-Brush-Generator Disadvantages

In its application to motorbus requirements, Mr. Skinner cited the following disadvantages of the third-brush generator:

(1) Overcharging batteries on long continuous driving, with the attendant troubles
(2) Undercharging batteries on slow, frequent-stop service
(3) Burning-out of lamps, due to their operation at an excess voltage
(4) Reducing the life of the lamps because of excess voltage, especially when the third brush has been advanced to boost output, on account of conditions arising such as low water in the battery, loose connections, poor wiring, or overloading
(5) The burning-out of field fuses and lamps if a battery connection becomes loose or disconnected
(6) That the generator must be used with the battery and will not carry the lamp load alone at the rated voltage
(7) That it does not give a tapering battery-charge, but maintains a comparatively high, steady rate
(8) The lamp voltage usually is higher than it should be, and causes a waste of energy
(9) That energy is wasted also because of maintaining a high charging rate

How Voltage Regulation Is Effected

Commenting upon the equipment for voltage regulation, Mr. Skinner said that it consists of a shunt-wound generator, either with or without a third brush, and a regulating unit to maintain a controlled voltage under the varying conditions of load, speed and temperature encountered in service. If the third-brush generator is regulated, the action of the extra brush is such as to protect the generator from severe overload automatically. If the straight shunt-wound generator is regulated, some overload protection, such as an overload circuit-breaker, should be used. Both methods have proved to be satisfactory in service.

Voltage regulation is effected by cutting resistance into the field circuit, thus weakening the field current to lower the voltage of the generator, and cutting this resistance out to cause the voltage to rise. If this resistance is cut-in and cut-out rapidly, an average condition of field strength will be maintained; that is, the field current will not have time to fall to the point corresponding to having all the resistance in, nor will it have time to rise to the point it would reach normally with all the regulating resistance out, on account of the rapidity of contact action and the inductanee of the circuit.

Instead of reaching the maximum and falling again to the minimum as contact is made and opened, the field current is suspended somewhere between these two extremes, which results in an intermediate value of field current and terminal voltage. If the contacts have a high frequency, there will be no perceptible flicker to the lamps; if the beat is slow and constant, flicker will result. The regulator must be designed so that it will respond to changes in the circuit; that is, it must function to raise the terminal voltage slightly under some conditions and to lower it under others.

Voltage Regulator

The 12-volt voltage-regulator described by Mr. Skinner is designed to furnish regulated voltage energy to battery and lighting circuits on motor vehicles; to maintain the voltage within limits required for sufficient, steady and non-flickering light from connected lamps; to assure long lamp-life by preventing excess voltage; and to provide the tapering charging-rate that is beneficial to the battery, which results automatically from regulated-voltage charging. It contains two distinct elements in the control box: A reverse-current relay or circuit-breaker, and a regulator element consisting of a specially constructed magnet and a pivoted armature that opens and closes a pair of contacts, called the "regulating contacts." Claims made for its advantages are that:

(1) An extremely high armature beat is attained, and it is responsive to changes of load and speed within the working range of any given system

(2) The contacts handle the in-setting and cutting-out of regulating resistance in an almost sparkless manner, so that they give long life and require little attention

(3) A very strong spring-tension is used and this provides a self-cleaning action on the contacts as well as making the instrument free from interruptions due to vehicle vibration

(4) Because metallic points are used, there is no danger of changing of adjustment due to contact wear as is true of carbon and similar materials when used as contact points

(5) The field circuit is never broken entirely; the regulating resistance is simply shunted

(6) A unique arrangement of connections provides the desired regulating characteristics, and flexibility ruptions due to vehicle vibration

Further, when the system is functioning properly, Mr. Skinner stated that:

(1) There will be very little variation, or no variation, in the intensity of light from connected lamps on sudden changes of load or engine speed

(2) A voltmeter, if connected across the load, will show a steady reading

(3) There will be little or no sparking between the contact points of the regulator

(4) The rate of vibration of the regulator armature will be steady and high; it will not "flutter" slowly back and forth, or stick in one position

(5) The variation of voltage with load disconnected, that is, with no lights or battery in circuit but with the regulator connected to the generator, will be very slight when the speed of the generator is raised or lowered rapidly, within the working range, above the point at which the circuit-breaker contacts close and the regulator begins to operate

After describing the regulator in detail, Mr. Skinner discussed curves illustrative of charging economics, compared current-regulation systems with voltage-regulation systems and then summarized the outstanding advantages of voltage regulation, as follows:

(1) A tapering battery charge is provided, and this prevents overcharging the battery

(2) A slight reduction in voltage on load can be provided as a protection to lamp life

(3) Steady, non-flickering light is assured either with a battery or without one

(4) The lamps can be operated without the battery, giving assurance against delays due to broken or loose battery connections and battery trouble

(5) Saving in energy results, as the battery is charged at the required rate; high when discharged and low when nearing full charge, and effecting a material power-saving

(6) Saving in energy delivered to the lamps results also, as they are operated very close to the correct voltage required for the highest efficiency

(7) Saving in lamps is made, due to the prolonged life afforded by the absence of excess voltage

(8) The condition of the battery does not affect lamp operation when the generator is running

(9) There is no danger of burning out lamps on account of excess voltage

(10) The battery is charged more nearly at the correct charging-rate

(11) Prolonged battery-life results from (10)

(12) Loose or corroded battery connections do not affect the operation of the lamps

(13) The electrolyte in the battery will not evaporate so rapidly

(14) The regulation is automatic

Mr. Skinner said that voltage regulation, as described, has received the hearty approval of both motorbus builders and operators.

Standard Motorbus Voltage Systems Compared

Mr. Michaud said that it is hardly possible to lay down any absolute rule for determining just what the voltage for motorbus lighting should be, because of the numerous items that must be taken into account in the selection of the electrical equipment. Since experience has demonstrated that each of the three standard voltages for motorbus usage, 6, 12 and 32-volt-systems, has certain advantages, he reviewed their respective merits to afford a basis of decision as to the voltage best suited for any particular motorbus application. The points in favor of the 6-volt-system are that:

(1) The 6-volt equipment is now standard on the majority of passenger cars and trucks. Hence the adoption of this system in motorbus service permits general uniformity of lamp bulbs, ignition apparatus, the starting motor and other items of equipment similar to those used in passenger car and in truck service. This reduces the variety of service parts it is necessary to carry in stock, and assures general availability of such standard parts from service-stations and from car dealers

(2) Lamp bulbs for 6-volt operation have heavier filaments that are somewhat less susceptible to the effects of vibration

(3) Where the voltage of the system is as low as 6 volts, less likelihood of short-circuits and grounds exists and less danger of electrolytic leaks as the result of moisture

(4) A 6-volt battery can be made to be somewhat more compact and lighter in weight than can one of higher voltage, because it requires only three cells

The chief reasons that commend the 12-volt-system for motorbus service are that:

(1) Wiring for the lamp circuits, as well as for the generating and the starting circuits, can be reduced to one-half the cross-section needed for the 6-volt system's wires because, for the same wattage, and on account of doubling the voltage, only one-half the current is needed. This also assists in reducing the voltage-drop in the lighting circuits to a point at which it does not affect the candlepower of the lamps seriously when the load is heavy

(2) Loose connections or extra resistance in the circuits will have a less pronounced effect upon the operation of the equipment than with the 6-volt system

(3) A starting motor for operation on 12 volts can be built to deliver high torque for heavy-duty engines without being of abnormally large size or weight

(4) The 12-volt generator can be built for a higher wattage output than can a 6-volt machine of the same size because, with the current-density in the windings and especially in the commutator and brushes decreased by one-half for any given wattage, the total output can be increased considerably without exceeding the safe capacity of the unit

(5) The 12-volt battery with its six cells is slightly larger and heavier than the 6-volt battery, but it has the advantage of being able to continue in reasonably satisfactory operation when one cell goes dead. Under such circumstances it would still be more than 83 per cent effective; but a 6-volt battery having one of its three cells defective would be only 67 per cent effective

(6) Although 12-volt equipment is used less extensively for automotive work than 6-volt equipment is, enough important users of 12-volt systems exist in the automobile and in the motor-truck fields, as well as in the motorbus field, to assure a universal supply of 12-volt bulbs, which are slightly higher in their watt-per-candle effectiveness as a rule. For example, the wattage of the 21 cp. 6 to 8-volt Mazda bulb is rated at 17.84, but the 12 to 16-volt bulb consumes only 16.82 watts for the same candlepower. Hence, where 10 or more lamps are used, as in the large-capacity motorbuses, this higher efficiency means an appreciable saving in the total lamp-load requirements

Especially when the total current requirements are about 1000 watts or higher, the 32-volt-system has certain advantages over the standard 6-volt and 12-volt automotive systems in that:

(1) For train-lighting work, 32 volts is the standard and, when used in motor rail-car service, it conforms with the prevailing railroad electrical-practice and so affords uniformity as to bulbs, wiring standards and the like

(2) The size of the wiring, especially in the lamp circuits, can be reduced very materially in the 32-volt system

(3) In the standard design used for 6 and 8-volt units, 32-volt starting-motors are practicable and have proportionately increased torque and horsepower over those of lower-voltage machines of the same size and weight

(4) While not altogether feasible in exactly the same design as the lower-voltage units, 32-volt generators can be built for higher output without having materially increased weight or size

Continuing, Mr. Michaud advised that all the significant points be reviewed carefully before arriving at a decision in regard to voltage, and that their bearing upon production costs and upon service maintenance be given due consideration. He pointed out the all-important fact that the automotive system still has to be classed as a low-voltage installation, compared with house-lighting and power voltages of 110 and 220 volts, and that the details of the wiring must be carried out in strict accordance with low-voltage practices such as have been established in electroplating and in telephone work.

Special attention should be given to wire sizes and lengths so as to minimize resistance losses, and all unnecessary resistance at terminal connections and splices must be eliminated. The terminals must have ample contact area to carry full-load current without appreciable voltage-drop, and they must also be substantial enough to remain tightened in spite of vibration and road shocks. The splices in the wiring must be well made and *soldered properly*, and as few splices as possible should be made.

The Discussion

It was brought out by A. J. Tierney, of the Electric Storage Battery Co., Chicago, relative to variable motorbus speeds, that this depends upon the nature of the motorbus service. He said that those in city service do not exceed from 12 to 14 m.p.h., but that others, in cross-country service, attain from 35 to 40 m.p.h. His company calculates that the generator should balance the lamp load at 10 m.p.h. motorbus-speed, irrespective of the type of service in which it is used, and that the generator must be capable of maintaining the current output at very low speed.

To the question as to whether the Society should standardize on a larger flange, asked by L. M. Kanters, of the Waukesha Motor Co., Mr. Skinner replied that the flanges at present known as standard are inadequate to support the overhanging weight of the larger generators without some additional means of support such as a bracket beneath the frame, a shelf on the back end-housing, or something similar. He mentioned that the question already had been raised regarding a flange large enough to support the generator without using additional means, and said also that this entails a problem for the engine builders, to provide a support larger than present standards to carry the additional weight.

Mr. Skinner stated that a generator of say 600-watt capacity should be driven through a flexible coupling and that the present disc-type couplings are scarcely adequate.

Other members and guests participated in questions and answers relating to details of battery and lamp sizes, desirable voltage and the like, following which a motion picture entitled Electricity in the Motor Vehicle was exhibited.

ELECTRICAL INSTRUMENTS DESCRIBED

Cleveland Section Meeting Great Success; J. H. Hunt Presents Valuable Paper

Music while you dine, interesting motion pictures of travel and an address on electrical research instruments by J. H. Hunt, head of the electrical division, General Motors Research Corporation, were among the features that forced the Cleveland Section to display the "Standing Room Only" sign at its Feb. 16 meeting at Hotel Hollenden.

By way of introduction Mr. Hunt said in part:

Research is a matter of *measurement* and *analysis*.

(*Continued on p.* 380)

Vol. XVI March, 1925 No. 3

The Automotive Airbrake —Why and How

By H. D. Hukill[1]

Detroit Section Paper *Illustrated with* Drawings and Photographs

ABSTRACT

In an endeavor to find an engineering justification for the use of the airbrake on automotive vehicles, an investigation was first made as to what actually causes a car to stop when the brakes are applied; and it was ascertained that nothing that can take place within the car itself can directly influence the motion of the automobile as a unit, that its motion can be changed only by some force external to the car itself.

Four such forces are normally present, namely, wind resistance, road resistance, gravity, and the adhesion of the road to the wheels. The first two are negligible. Grades have a measurable effect on the stopping distance, but the force that actually stops the car is the last named: the force that is applied from a point external to and in a direction opposite to that of the motion of the automobile. This frictional force is called into existence by the resistance that the brake-bands offer to the continued rotation of the wheels, the maximum possible road adhesion occurring when it is equal to the coefficient of adhesion multiplied by the weight carried by the wheels. If the brake-band pressure is greater than the maximum possible adhesion, the wheels will lock and a transfer of energy will take place between the sliding tires and the surface of the road. The shortest possible stopping distance is obtained when all braked wheels are held just short of the point of locking throughout the duration of the stop.

Friction is defined as the resistance of two bodies in contact that opposes a change in their relative positions. When the friction is greater than a force that tends to produce motion, the friction is termed "static" friction, or friction of rest; when the impelling force is greater than the resistance of friction and one body slides over the other, the friction is termed "kinetic" friction, or friction of motion. Rolling friction between a rolling wheel and the road is static friction, for the point of contact does not move. For the sake of simplicity, this is termed "adhesion," to distinguish it from the kinetic friction that exists between the brake-band and the brake-drum mounted on the wheel.

Every surface, no matter how highly polished it may be, contains humps and depressions that tend to interlock or mesh with those of other surfaces, like the teeth of two gears. Static friction is always greater than kinetic friction because these humps and depressions have a greater opportunity of becoming interlocked. When in relative motion, two surfaces have not time in which to become interlocked, and each surface hits only the high spots of the other. Consequently, the friction becomes less as the velocity increases.

After these preliminary observations, the author discusses the variations of the coefficient of friction of different kinds of brake-lining under varying conditions, develops formulas to show the forces necessary to lock the wheels of a car under given conditions, and determines the amount of push of the pedal or pull of the lever that would be necessary to produce this effect with various arcs of contact between the brake-shoe and the drum.

With consideration for operating and maintenance requirements, the best practice in heavy-vehicle design is said to have determined that the maximum total multiplication between the pedal input and the cam output is about 36, and between the hand-lever and the cam, about 50. Inasmuch as an average man can exert a push of approximately 200 lb. on the pedal and a pull of 150 lb. on the hand-lever, the statement is made that, under the best possible operating conditions, either hand or foot-actuated rear-wheel brakes are inadequate to produce the shortest possible stop in any vehicle having a gross weight of more than 7500 lb. Under the worst combination of operating conditions, it is probable that the weight that could be so controlled would not exceed 3500 lb. If a braking pressure sufficient to lock the rear wheels is not available, the addition of front-wheel brakes operated from the same actuating source will not reduce the stopping distance, but, in fact, will increase it.

The limitations of propeller-shaft service or foot-brakes, or internal and external-band brakes, and of mechanically actuated and self-energizing servo-brakes are outlined, and the conclusion is reached that, in order adequately to brake vehicles weighing more than 5000 lb., a power brake is essential.

With the object of applying more force with greater flexibility to existing brake-riggings, the Westinghouse automotive airbrake has been developed, the details of which are described with copious illustrations.

THE question is often asked, "Why is an airbrake necessary?" The man that drives a motorbus or a motor truck 10 hr. a day replies, "To relieve me of physical exertion on this back-straining man-killing job." The safety director replies, "To reduce the ever-increasing number of traffic accidents." The transportation manager replies, "To reduce maintenance cost and to speed-up the schedule." The owner of a heavy passenger-car replies, "To give me a car that my wife can handle with ease and confidence, a car in which I can tour without becoming fatigued."

It is the intention of this paper to show the engineering justification, or what might better be termed the engineering necessity for a power-brake on motorbuses, motor trucks and the heavier passenger-cars and to describe an airbrake equipment that has been designed to meet the requirements of this service. The design of mechanical brake-mechanisms is beyond the scope of this paper but a number of fundamental factors that are involved in brake design must be considered.

First, let us consider what actually stops a car when the brakes have been applied. Suppose an automobile moving along a road is suddenly lifted into the air by a rope attached to a balloon far overhead traveling at the same rate as the automobile. The automobile will still move with the same speed that it moved on the road and

[1] M.S.A.E.—In charge of automotive division, Westinghouse Airbrake Co., Wilmerding, Pa.

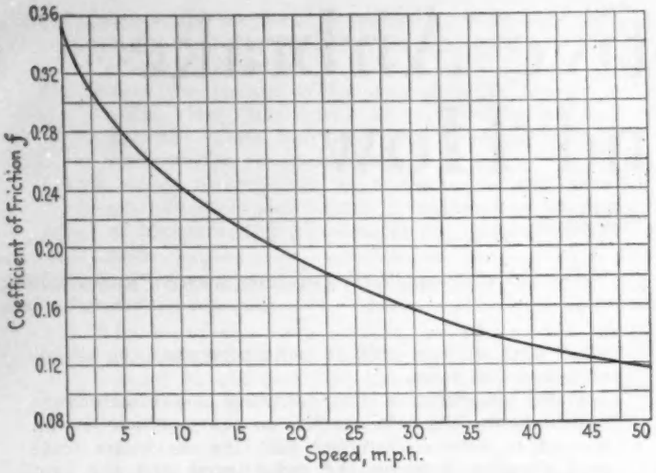


FIG. 1—CURVE SHOWING VARIATION OF THE COEFFICIENT OF FRICTION OF CAST IRON ON STEEL WITH SPEED, ALL OTHER FACTORS REMAINING CONSTANT
The Value of the Coefficient at 40 M.P.H. Is Less than One-Half Its Value at 5 M.P.H.

its wheels will still rotate at their accustomed rate. If now the brakes are applied to the wheels the only effect will be to stop the rotation of the wheels. The car with its wheels locked will move forward through the air at exactly the same speed that it had before the brakes were applied. From this illustration it will be evident that nothing that occurs within its own mechanism can, by any operation whatever, directly influence the motion of the automobile as a unit. The condition of motion can be changed only by the application of some force external to the automobile itself.

Four such forces are normally present: (*a*) wind resistance, the effect of which depends upon air currents and the exposed area of the car; (*b*) road resistance, which retards the rotation of the wheels and depends upon the condition of the surface of the road and the condition and the style of the tires used; (*c*) gravity, which has a retarding effect on up-grades and an accelerating effect on down-grades; and (*d*) the road, which through adhesion, exerts a force on the wheels that tends to prevent them from rotating.

The effect of the first two forces mentioned is relatively small and, in most calculations, may be neglected. Grades have a definite measurable effect on the possible stopping distances that may be introduced as a factor to modify calculations based on level roads; the effect of grades on the amount of energy to be dissipated by the brakes will be discussed later.

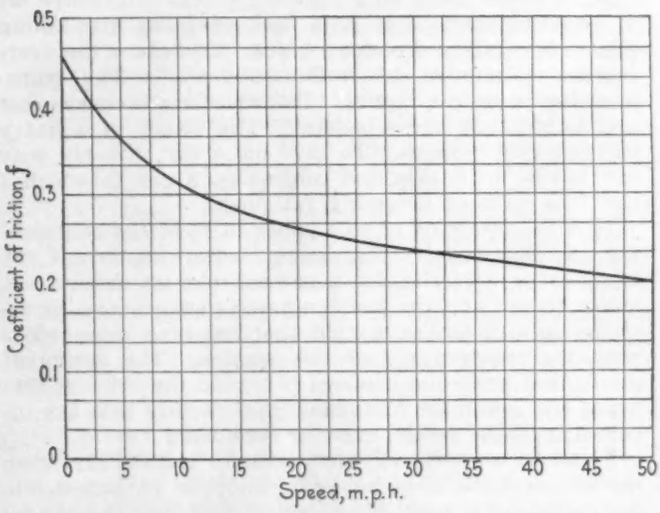


FIG. 2—VARIATION OF THE COEFFICIENT OF FRICTION OF FABRIC BRAKE-LINING ON A PRESSED-STEEL DRUM WITH THE SPEED
This coefficient Varies over a Wide Range Depending on the Length of Time that the Materials Have Been in Contact and on the Presence of Oil or Moisture

The force last mentioned, applied from a point external to and in a direction opposite to that of the motion of the automobile, is the one that actually stops the car. This frictional force exerted by the road upon the wheels is developed by the resistance that the brake-bands offer to the continued rotation of the wheels, the brakes having no other function in stopping the car than to call this force into existence. The maximum possible road-adhesion is equal to the coefficient of adhesion multiplied by the weight carried by the wheel; and, normally, when the brake-band friction is less than the maximum possible adhesion, a transfer of kinetic energy into heat takes place between the brake-band and the brake-drum. If, however, the brakes are applied with sufficient pressure to make the friction of the brake-band greater than the maximum possible adhesion, as is often the case on icy streets when the adhesion is low, the wheel will lock, and a transfer of energy will take place between the sliding tire and the surface of the road.

The shortest possible stopping-distance of any vehicle is obtained when all the braked wheels are held just short of the point of locking throughout the duration of the stop. This is true, because the coefficient of road adhesion has a greater value than the coefficient of kinetic friction between the tire and the road. For the same reason, the proper method of obtaining traction with a car whose driving-wheels are spinning on a slippery ascent is to stop entirely and to begin again very slowly, with gradual acceleration. A car with perfectly equalized brakes can be stopped in a considerably shorter distance than can a car on which one rear wheel is locked and the other is rolling.

Since it is friction between the tires and the road, developed by application of frictional force to the brake-drums, that stops a car, we should next consider some of the fundamentals of friction and how they affect the problem of braking. Friction may be defined as the resistance of two bodies in contact, offered by each one to the other, that opposes a change in their relative positions. This resistance is offered along the surfaces in contact, and is directly opposed by the force along the surfaces that produces, or tends to produce, relative motion. When this force is not sufficiently great to overcome the friction, no motion will take place; and the friction is referred to as "static friction," or "friction of rest." When the impelling force is greater than the resistance of friction and one of the bodies slides over the other, the friction is termed "kinetic friction," or "friction of motion."

Rolling friction between a rolling wheel and the road is static friction, for the point of the tire tread in contact with the road does not move or slide relatively to the road. Another way of expressing this relation is to say that, during a revolution of the wheel, each point around the tread of the wheel comes into contact with only one point on the road and, using the automobile as a reference point, the road is moving backward at a rate equal to the tangential velocity of the tire. For the sake of simplicity, the static friction between the road and the wheel is given the name "adhesion" to distinguish it clearly from the kinetic friction that exists between the brake-band and the brake-drum mounted on the wheel.

Every surface, no matter how highly polished it may be, contains mounds and depressions. One theory of friction is that these humps and hollows on the two surfaces in contact tend to interlock or to mesh, like two gears. The smaller the humps and hollows are, which is another way of saying, the smoother the surfaces are, the less will be the friction and the force necessary to cause one body to slide over the other. To return to the illustration of two gears: The smaller the gear teeth are, the smaller is the distance that one gear must move away from the other to ride over the teeth, and the easier it is to strip off the teeth.

Static friction, or friction of rest, is always greater than kinetic friction, or friction of motion, because, while at rest, the humps and hollows have the best possible opportunity of becoming thoroughly interlocked. When one surface is sliding over another, the humps of one surface have not time in which to drop into and to fit the corresponding hollows of the other; each surface has the "jump" on the other and "hits only the high spots." As the velocity of one surface increases with respect to the other, the more does this become true, that is, as the velocity increases, the less does the friction become.

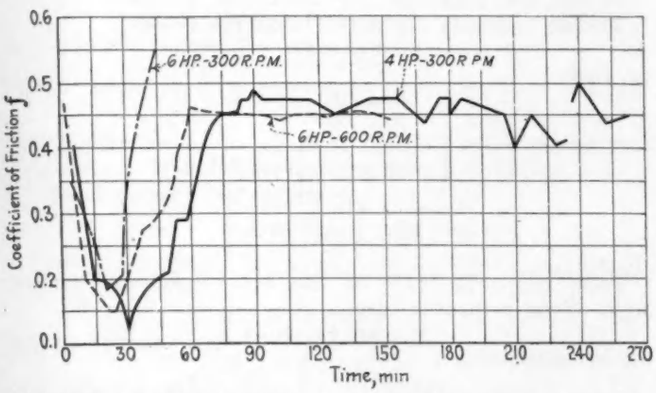


FIG. 3—CURVE SHOWING VARIATION OF THE COEFFICIENT OF FRICTION OF FAERIC BRAKE-LINING ON AN UNCOOLED DRUM WITH THE DURATION OF RUBBING

After a Run of Approximately 20 Min., the Friction of All Three Samples Was Reduced to Less than One-Half Its Original Value

Fig. 1 shows the variation in the coefficient of friction with speed, all other factors being constant, of a cast-iron brakeshoe bearing on a cast-steel wheel. It should be noted particularly that the coefficient of friction at 40 m.p.h. is less than one-half its value at 5 m.p.h.

Incomplete tests on woven-fabric brake-linings indicate a variation, as is shown in Fig. 2. Actual rubbing-speed has been translated into the equivalent car-speed, on the assumption that the outside diameter of the tire is twice the diameter of the brake-drum.

The coefficient of friction of fabric brake-linings also varies over a wide range, depending on the length of time that the lining has been in contact with the drum and on the presence of oil or moisture. These factors were discussed by S. Von Ammon in a very comprehensive paper[2] presented at the 1922 Annual Meeting of the Society in which he described the results of brake-lining tests made at the Bureau of Standards. I am taking the liberty of reproducing two of the charts exhibited by Mr. Von Ammon.

Fig. 3 shows the variation of the coefficient of friction with the duration of rubbing and, incidentally, the life of three samples of brake-lining that have been used

[2] See THE JOURNAL, March, 1922, p. 153.

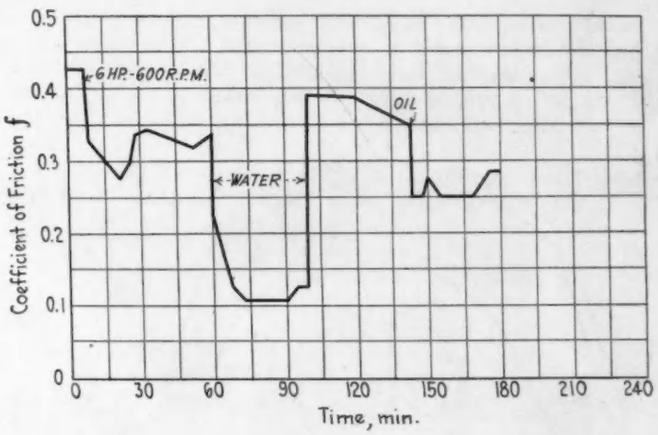


FIG. 4—CURVE SHOWING INFLUENCE OF WATER AND OIL ON THE COEFFICIENT OF FRICTION OF WOVEN BRAKE-LINING ON A COOLED DRUM AFTER UNDERGOING SERVICE ON AN UNCOOLED DRUM

Water Reduced the Coefficient by More than 50 Per Cent; Oil by Approximately 30 Per Cent

on an uncooled brake-drum 14.5 in. in diameter by 2.5 in. wide. After a run of approximately 20 min., the friction of all three samples was reduced to less than one-half its original value.

Fig. 4 shows the influence of water and oil on a sample of woven brake-lining that has already undergone service tests on an uncooled drum. Water sprayed on the lining reduced its coefficient of friction by more than 50 per cent, whereas the presence of a liberal supply of oil reduced the coefficient of friction by approximately 30 per cent.

It has been shown that the shortest stop is made when the wheels are held just short of sliding throughout the length of the stop, that is, at the point of the maximum adhesion; that the magnitude of the retarding force depends upon the friction force created at the brake-bands; and that the friction at the brake-bands decreases as the speed is increased. It follows, then, that the most effective brake is the one that is capable of applying a force at the brake-bands so that the maximum road-adhesion at high speeds will be utilized, and that is flexible enough to allow the applied force to be decreased in accordance with the increase of brake-band friction as the speed decreases.

The following method of calculating the braking force required to lock the wheels on any vehicle is sufficiently accurate for all practical purposes. Any retarding effect produced by wind resistance, road resistance, and bearing, transmission or engine resistance is ignored. Considering the wheel brakes to have internal-expanding rigid shoes, the moment of braking friction for a condition of locked wheels must be equal to and must balance

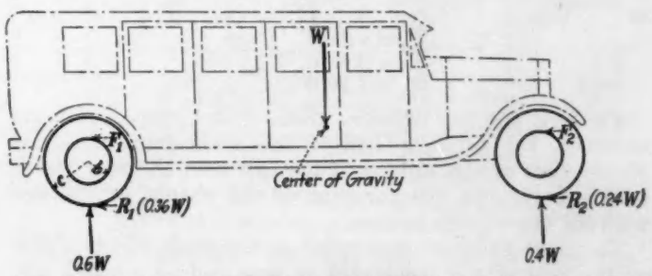


FIG. 5—DIAGRAMMATIC REPRESENTATION SHOWING CAR AS A FREE BODY

Car Is Considered as Having but Two Wheels, One Rear and One Front, and Definite Values Have Been Assigned to the Factors Involved

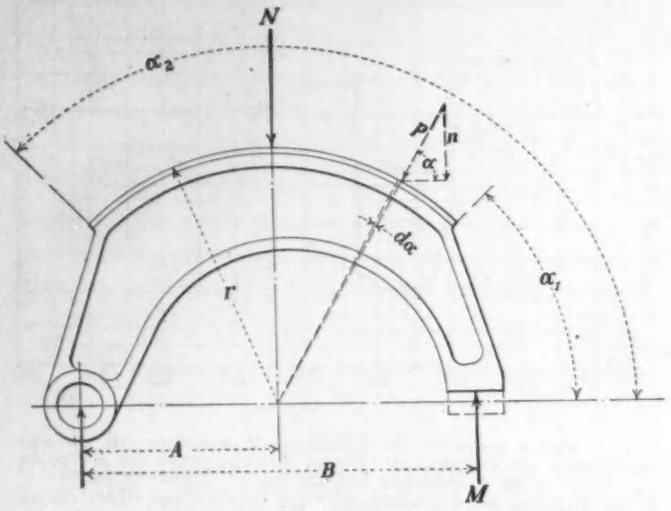


FIG. 6—DIAGRAMMATIC REPRESENTATION OF BRAKE-BAND
From These Values an Expression Is Derived for the Value of the Total Retarding Force

the moment of road adhesion. This is true for any and for all wheels; the possible stopping-distance depends on the percentage of the total weight carried by the braked wheels.

For the sake of simplicity, the car will be considered as having but two wheels, one rear and one front wheel, and definite values have been assigned to the factors involved. Referring to Fig. 5, which shows the car as a free body,

$F = F_1 + F_2$, the total retarding force at the brake-drums
$f = 0.35$, the average coefficient of fabric brake-lining friction under the best conditions
$R = R_1 + R_2$, the total available rolling force at the wheels ($R = 0.6\ W$)
W = the total weight, considered as divided 60 per cent on the rear wheels and 40 per cent on the front wheels and neglecting any transfer of weight during retardation
0.60 = the coefficient of road adhesion
0.75 = the efficiency of the brake rigging under the best conditions, when including brake-release springs

In most conventional brake-designs, the radius of the tire is approximately twice the radius of the brake-drum, so it is assumed that

$$c = 2\,b$$

For a condition of locked wheels, the brake couple equals the road couple at each wheel.

$$F_1 b = R_1 c$$
$$F_2 b = R_2 c$$

or

$$F_1 = 0.72\ W$$
$$F_2 = 0.48\ W$$
$$F = 1.20\ W$$

To lock the car wheels, then, under the conditions assumed, the force applied to the brake-drum must be 72 per cent of the weight of the car with the rear-wheel brakes only, and 120 per cent of the weight of the car with all the wheels braked.

The next thing to determine is the push of the pedal or the pull of the lever that is required to produce the retarding force F at the brake-drums. This calculation will be carried through for the internal-expanding rigid-shoe brake, as this is one of the most common and most satisfactory types of brake from the standpoint of design.

Considering one brake-head as a free body, Fig. 6,

a = Angular distance, in radians, from the horizontal reference line at any point on the brake-shoe
f = Coefficient of brake-lining friction
M = Force imparted to the brake head from the cam
N = Summation of the vertical components, n, of all radial forces imposed by the drum, when considered as acting through the center of the head
p = Unit radial force-reaction from the drum, the brake-head being considered as 1 unit wide
r = Radius of the brake-head

Considering a segment of the shoe $d\alpha$ in width, the area $= r\ d\alpha$ and the total radial pressure $= pr\ d\alpha$

$$n = \alpha\ pr\ d\alpha\ sin\ \alpha$$

Over the entire surface

$$N = \int_{\alpha_1}^{\alpha_2} pr \sin\alpha\, d\alpha = \Big[-pr\cos\alpha \Big]_{\alpha_1}^{\alpha_2}$$

Taking moments about the hinge-pin center,

$$NA = MB,$$

or, since

$$B = 2A$$
$$N = 2M$$
$$\Big[-pr\cos\alpha \Big]_{\alpha_1}^{\alpha_2} = 2M$$
$$p = 2M \Big/ \Big[-r\cos\alpha \Big]_{\alpha_1}^{\alpha_2}$$

Total radial pressure on the brake-head $= pr\ (\alpha_2 - \alpha_1)$. Total retarding force,

$$F = prf\ (\alpha_2 - \alpha_1)$$

or, by substitution,

$$F = 2\,fM\ (\alpha_2 - \alpha_1) \Big/ \Big[-\cos\alpha \Big]_{\alpha_1}^{\alpha_2}$$

The expression $(\alpha_2 - \alpha_1) \Big/ \Big[-\cos\alpha \Big]_{\alpha_1}^{\alpha_2}$ is a factor that may be represented by K and depends entirely on the angular length of the brakeshoe. It is also based on

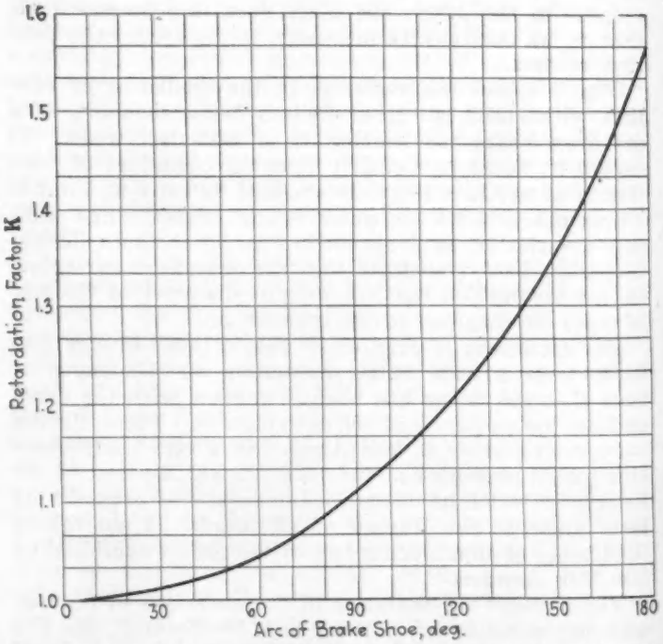


FIG. 7—CURVE SHOWING VARIATION OF THE RETARDING-FACTOR K WITH THE ARC OF CONTACT OF THE BRAKESHOE
This Factor Is Based on the Assumption of an Exact Fit of the Brakeshoe and the Brake-Drum

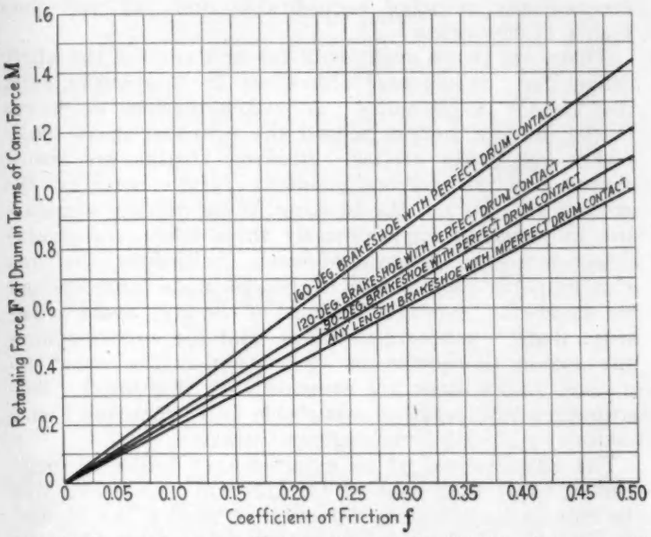

Retarding Force F at Drum in Terms of Cam Force M
Coefficient of Friction f
160-DEG. BRAKESHOE WITH PERFECT DRUM CONTACT
120-DEG. BRAKESHOE WITH PERFECT DRUM CONTACT
90-DEG. BRAKESHOE WITH PERFECT DRUM CONTACT
ANY LENGTH BRAKESHOE WITH IMPERFECT DRUM CONTACT

FIG. 8—CURVE SHOWING EFFECT OF THE BRAKESHOE ARC ON THE COEFFICIENT OF FRICTION

Perfect Drum-Contact Is Assumed for Brakeshoes of 90, 120 and 160-Deg. Lengths

the assumption of the exact fit of the brakeshoe and the brake-drum, and is represented graphically in Fig. 7.

The equation then reduces to

$$F = 2\,fMK$$

For a condition of locked wheels with rear-wheel brakes.

$$0.72\,W = 2\,fMK$$

or,

$$M = 0.36\,W/fK$$

With four-wheel brakes,

$$M = 0.6\,W/fK$$

Under the worst conditions, with only line contact between the drum and the brakeshoe, as may be imagined, if the drum is badly out-of-round or the lining has worn irregularly, K becomes 1, and the net retarding force at the drum is equivalent to twice the force applied by the cam, multiplied by the coefficient of brake-lining friction.

K increases with an increase in the arc of contact between the brakeshoe and the drum, up to a value of 1.57 with a 180-deg. arc of contact. As previously noted, this increase is based on an exact fit and complete contact between the brakeshoe and the drum. To take advantage of this factor, axle manufacturers give brake-drums a ground finish, and some chassis builders also grind the brake-band assembly. Such a brake will perform well on factory test, but will become less effective with service, especially if it has been relined in the field. This may be graphically illustrated by plotting the retarding force, F, in terms of the cam force, M, against the coefficient of friction, f, for brakeshoes of various arcs.

Fig. 8 shows these curves for brakeshoes of 90, 120 and 160-deg. lengths. Perfect drum-contact is assumed and values of K are chosen from Fig. 7. The same curve is plotted for any length of brakeshoe having only line contact or a very poor drum fit, with K equaling 1. With a lining coefficient of friction of 0.35, a 90-deg. brakeshoe with imperfect drum-contact requires 11.5 per cent more force at the cam, to produce the same retarding effect, than does the same shoe with perfect contact. With a 160-deg. arc of lining contact per shoe this percentage is increased to 43.

With consideration for operating and maintenance requirements, the best practice in heavy-vehicle design has determined the maximum total multiplication between the pedal input and the cam output to be about 36, and between the hand-lever and the cam to be about 50.

Designating the pedal force by X and the hand-lever pull by Y, with 75 per cent brake-rigging efficiency,

$$M = 0.75\,(36X) = 27X$$
$$M = 0.75\,(50Y) = 37.5Y$$

To lock the wheels with rear-wheel brakes,

$$M = 0.36\,W/fK$$

or

$$X = 0.0133\,W/fK$$
$$Y = 0.0096\,W/fK$$

To lock the wheels, with the total weight carried on braked wheels,

$$M = 0.6\,W/fK$$

or

$$X = 0.0207\,W/fK$$

Any brake, to be considered as 100 per cent effective, should be capable of practically locking the wheels on a hard, dry, level road. This provides an emergency reserve that may seldom be required but, in that very emergency, a foot may save a life!

Curves may now be plotted showing the pedal force or lever pull required to lock the braked wheels on a level road with the type of brake just described. Assuming a coefficient of friction of 0.35 for the lining and perfect contact between the drum and the lining, the forces required for various vehicle weights are shown in Fig. 9. An average man can exert a pedal force of approximately 200 lb., and pull of 150 lb. on a hand-lever. On this basis, with the assumption of the best possible operating-conditions upon which these curves are predicated, it is apparent that either hand or foot-actuated rear-wheel brakes are inadequate to produce the shortest possible stop on any vehicle with a gross weight of more than 7500 lb. With the worst combination of operating conditions, the brake-rigging efficiency may be reduced from 75 to 50 per cent, the coefficient of brake-lining friction may be reduced from 0.35 to 0.15 and the factor K may be 1, so that a car

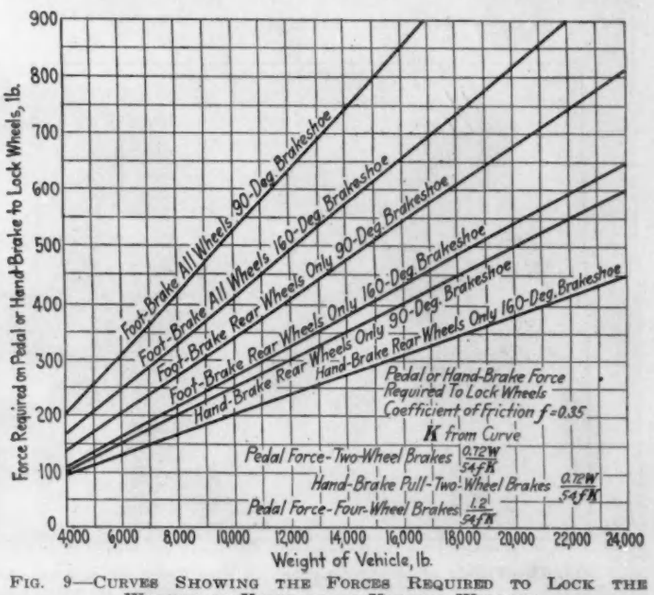

Force Required on Pedal or Hand-Brake to Lock Wheels, lb.
Weight of Vehicle, lb.
Foot-Brake All Wheels 90-Deg. Brakeshoe
Foot-Brake All Wheels 160-Deg. Brakeshoe
Foot-Brake Rear Wheels Only 90-Deg. Brakeshoe
Foot-Brake Rear Wheels Only 160-Deg. Brakeshoe
Hand-Brake Rear Wheels Only 90-Deg. Brakeshoe
Hand-Brake Rear Wheels Only 160-Deg. Brakeshoe
Pedal or Hand-Brake Force Required To Lock Wheels
Coefficient of Friction f=0.35
K from Curve
Pedal Force-Two-Wheel Brakes 0.72W/54fK
Hand-Brake Pull-Two-Wheel Brakes 0.72W/54fK
Pedal Force-Four-Wheel Brakes 1.2W/54fK

FIG. 9—CURVES SHOWING THE FORCES REQUIRED TO LOCK THE WHEELS OF VEHICLES OF VARIOUS WEIGHTS

Either Hand or Foot-Actuated Rear-Wheel Brakes Are Inadequate To Produce the Shortest Possible Stop if the Vehicle Has a Gross Weight of More than 7500 Lb.

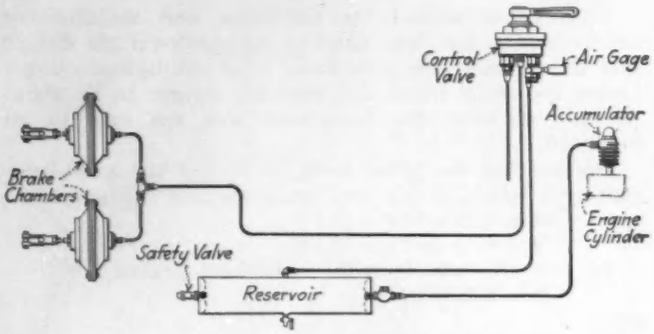


FIG. 10—PIPING DIAGRAM OF AN AUTOMOTIVE AIRBRAKE SUITABLE FOR LIGHT CARS

More Force with Greater Flexibility Can Be Applied to Existing Brake-Riggings than Is Possible through Hand or Foot-Operated Mechanisms

weighing 3500 lb. or even less could not be adequately controlled with foot or hand-actuated brakes.

It is evident that, when a braking-pressure sufficient to lock the rear-wheel brakes is not available, the addition of front-wheel brakes operated from the same actuating source will not reduce the stopping-distance; in fact, because of the additional release springs and the increased rigging losses, the stopping-distance with four-wheel brakes is actually increased above that which is accomplished with rear-wheel brakes only. From the curves of Fig. 9, the full advantage of a foot-actuated four-wheel brake, under the best conditions, is possible with a 5000-lb. car; under average or poor operating-conditions, the possible weight of the car would be reduced to 2500 lb. or less.

Braking performance of motorbuses and motor trucks, and even of the heavier passenger-cars with brakes as just described, would be not only unsatisfactory but dangerous to the public. It is true that a great many of the motorbuses and motor trucks on the streets are capable of developing a more effective retarding force than the foregoing figures would indicate. Various methods are used to accomplish this. Some of these practices are: (*a*) propeller-shaft service, or foot brakes, (*b*) external-band brakes, (*c*) internal-band brakes, (*d*) mechanically actuated servo-brakes and (*e*) self-energizing servo-brakes.

There are many arguments for and against the shaft brake but fundamental objections to this brake exist that cannot be overcome. A broken member anywhere in the driving system behind the propeller-shaft brake makes the brake useless. Braking strains are transmitted through driving elements before reaching the ground and, during the braking, these driving elements are subjected to approximately three times the strains of acceleration. Because of space limitations, the area of a propeller-shaft brake cannot be made large enough for heavy-duty service. Because of the high speed of the drum under running conditions, and the corresponding increase in the coefficient of friction as the speed decreases, rough stops are common with this brake. The propeller-shaft brake is acceptable only when used as a holding or so-called "emergency" brake.

The effectiveness of an external-band brake is somewhat greater than that of the internal-shoe brake, and the effectiveness for one direction of motion can be further increased by placing the anchor-point so that greater "wrapping" effect will be secured. This is fully covered in an article by P. M. Heldt[3]. Motorbuses are on the roads today that have external-band brakes anchored at one end, which are giving the maximum possible wrapping effect in the forward direction and practically no braking in the reverse direction.

The external-band brake also has disadvantages and is being discarded as a service brake for commercial vehicles in heavy-duty service. The brakes are on the outside of the drum and have no protection; dust or dirt entering between the lining and the drum acts as an abrasive, shortening the life of the linings and of the drums. This brake is also partly exposed to water and to splash on wet roads; the lining friction is greatly reduced, and trouble may also be caused by freezing in cold weather.

Heat radiation from the drum is considerably less with the external than with the internal band brake; and this condition is further aggravated when external and internal band-brakes are applied to the same drum. With such construction, trouble is certain, especially when the brakes are given severe use on hills.

It is very hard to keep external-band brakes properly

[3] See *Automotive Industries*, Aug. 30, 1923, p. 424.

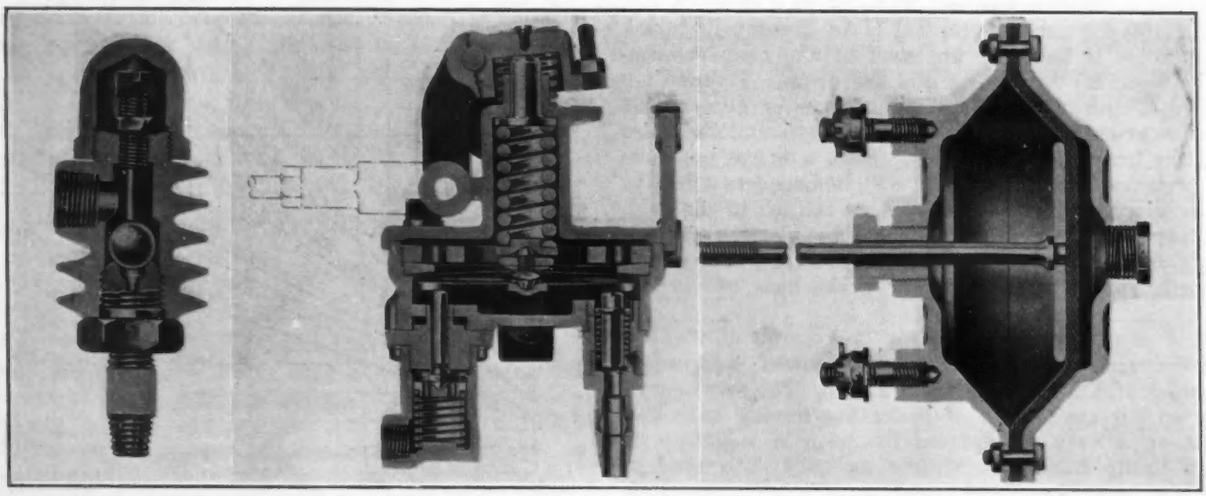


FIG. 11—VIEWS OF ACCUMULATOR, AT THE LEFT, OF SPECIAL RELAY OR APPLICATION RELEASE-VALVE, IN THE CENTER, AND OF BRAKE CHAMBER, AT THE RIGHT, FOR AUTOMOTIVE AIRBRAKE

Details of the Accumulator Differ from Those of Earlier Forms Used To Produce an Air Supply for Self-Starters and Air-Whistles: the Release-Valve Is Interposed between the Brake-Valve and the Brake Chambers; the Diaphragm Is Normally in Such a Position That the Exhaust-Valve Is Slightly Open

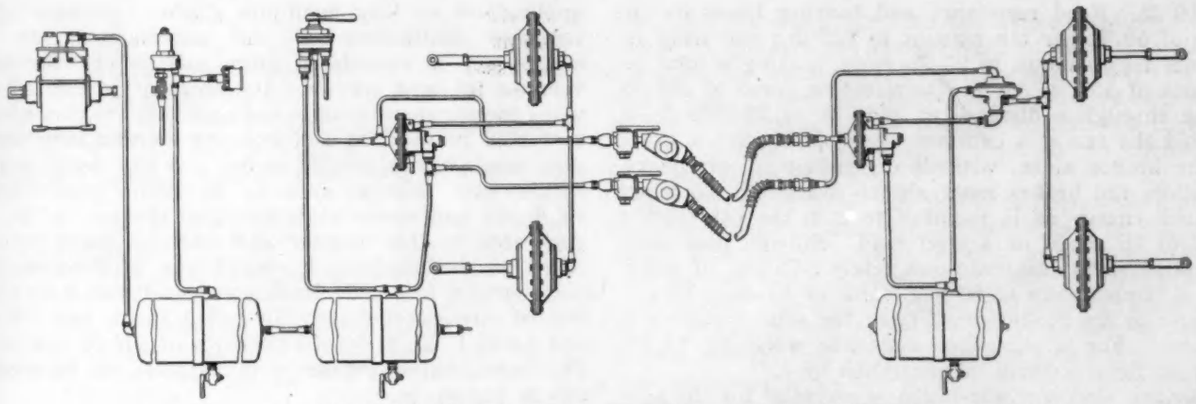


FIG. 12—PIPING DIAGRAM FOR USE WITH MOTOR TRUCKS AND TRAILERS
This Layout Is Designed for a Reversible Trailer with a Drawbar Attachment at Each End

equalized, because the coefficient of friction has a greater relative effect upon the ultimate retarding force than is the case with rigid-shoe brakes, and with an exposed brake the coefficient of friction is a most variable factor.

The tendency with most external-band brakes, after they have been in service for some time, is decidedly toward squealing; and, in some localities, this condition is becoming so serious that newspapers, hospitals and other public institutions are requesting legislative action to keep squealing brakes off the highway.

Some of the points mentioned concerning the external-band brake also apply to the internal-band brake.

Mechanically actuated servo-brakes are not being used to a great extent in this Country because of the complications of present designs. Absolute reliability is also a factor that must be considered in such a brake.

Self-energizing servo-brakes, consisting of two or more internal shoes, with one shoe arranged to "pick-up" the other, to give a heavy wrapping effect, are coming into use and will undoubtedly occupy an important place in four-wheel passenger-car equipment. Here again any variation in the coefficient of friction is multiplied in the final braking effect. High-speed motorbus brakes appear to depend on rigid anchoring to prevent chattering.

Some recent four-wheel passenger-car brake-designs provide for a variable linkage-multiplication ratio so that, after the pedal has been depressed sufficiently to take-up slack, the leverage ratio is automatically increased, producing a correspondingly greater braking-effect at the drum.

Stoppage tests, made on more than 100 cars, motorbuses and motor trucks brought in from the road, show the ineffectiveness of the average present-day braking-system after 5000 miles or more of service. Airbrakes were applied to the existing linkage when the original manual brake-rigging was considered sufficiently sturdy for operation with higher braking-pressures and the average stopping-distance of a 12,000-lb. motorbus could be shortened one-third with the airbrakes, and the stopping-distance of a loaded truck of 3½-ton capacity, or more, could be cut in half.

Some decided changes in braking systems may be expected as soon as motorbuses and motor trucks are subjected to periodic braking-tests.

A committee appointed by Secretary of Commerce Hoover has recently made the following recommendations:

> Pending the adoption by constituted authorities of a code for standard braking-ability, which is now in course of preparation, all motor vehicles, except possibly motorcycles and heavy trucks, should be capable of stopping from a speed of 20 m.p.h. on a dry smooth hard-surfaced road, free from any loose material, by the service-brake alone in a distance of not more than 50 ft.

This is liberal, as a theoretical or calculated stop within 35 or 40 ft. is possible with two-wheel brakes. But why consider the exclusion of heavy trucks from this regulation when these are the very vehicles that present the greatest accident hazard? The most heavily loaded train in the New York City subways is stopped as quickly as is the one-man street-car.

Heat-radiating ability or braking capacity is an important factor in all brake design. Consider a loaded passenger-car weighing 5000 lb. to be controlled at 15 m.p.h. down a 10-per cent grade ½ mile long, the equivalent of which is found on many of our National highways.

The kinetic energy of the car at the top of the grade is $0.0334\ Wv^2$ or 37,575 ft-lb., which is the energy dissipated when the car is stopped on a level road. On a 10-per cent grade, the force component parallel to the road and accelerating the car downhill is 0.10 x 5000,

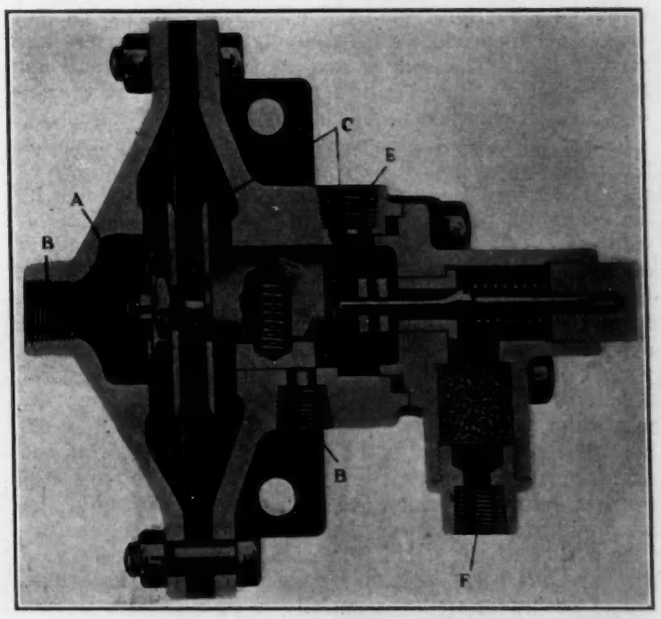


FIG. 13—APPLICATION RELEASE-VALVE
When Air Is Admitted to the Brake Pipe from the Brake-Valve, the Diaphragm Is Deflected Inwardly To Close the Exhaust-Valve and To Open the Inlet-Valve, Thus Allowing Air To Flow from the Reservoir to the Brake Chambers

or 500 lb. Road resistance and bearing losses on the basis of 50 lb. per ton amount to 125 lb.; and wind resistance may amount to 25 lb. more, making a total resistance of 150 lb. A net accelerating force of 350 lb. acting through a distance of 2640 ft. is 924,000 ft.-lb. To hold the car at a constant speed down such a grade by the brakes alone, without depending on engine retardation, the brakes must absorb practically 25 times as much energy as is required to stop the car from a speed of 15 m.p.h. on a level road. Enough heat must be dissipated to evaporate completely 8.75 gal. of water from a temperature of 60 deg. fahr. or to raise 65 gal. of water to the boiling-point from the same initial-temperature. For a passenger motorbus weighing 15,000 lb., these figures would be multiplied by 3.

Believing that a power brake is essential for the adequate braking of vehicles weighing more than 5000 lb., for the reasons already mentioned, the Westinghouse automotive airbrake has been developed to meet these requirements.

The fundamental equipment was designed with the main thought of applying to existing brake-riggings, more force, with greater flexibility, than is possible through hand or foot-actuated mechanisms.

This equipment, as used for passenger cars, is shown in Fig. 10. The air supply is secured through an accumulator, or ball check-valve, connected with the combustion-chamber of one of the engine cylinders and carried to a storage reservoir. An auxiliary check-valve may be included between the accumulator and the reservoir, to ensure against leakage of reservoir pressure after the engine has been stopped, in case carbon or other solid matter is lodged under the accumulator valve-seat. A safety-valve is mounted on the reservoir, to comply with legislation in certain States requiring a safety-valve on all compressed-air systems. From the reservoir, the air flows through a regulating type of brake-valve to the brake chambers, which are connected with the mechanical brake linkage.

The accumulator, as shown at the left of Fig. 11, was designed especially for airbrake service, and differs in detail construction from earlier forms of this device that were used to produce an air-supply for self-starters and air-whistles. The body is made of cast copper and has heat-radiating fins; because of the high operating-temperatures encountered, the ball, ball-seat and adjusting-stud are all made from special alloy-steel. The accumulator functions best with a ball lift of 1/64 in., which may be determined by backing off the adjusting-stud one-quarter turn from the solid position and locking it into place. The pressure derived from the accumulator depends on the condition of the engine and the work being done by it. With a clean engine pulling a load, from 150 to 200-lb. per sq. in. reservoir-pressure may be expected; with an idling engine, not more than 50 lb. per sq. in. will be obtained. The maximum capacity of the accumulator is 0.7 cu. ft. of free air per min.; the maximum power taken from the engine cylinder is 0.3 hp. The accumulator ball lifts only at the peak of the explosion-stroke and, after the reservoir pressure has reached a point at which the back pressure on top of the accumulator-ball balances the explosion pressure, no further action of the valve takes place until the reservoir pressure has been depleted by applications of the brake.

The accumulator is essentially a light-service device and is very satisfactory within this field. Although the accumulator is not effective on an idling or coasting engine, the reservoir capacity can be proportioned so that sufficient air will be in reserve for 40 or more brake applications on long mountain grades. Because of the inherent limitations of the accumulator, an air-compressor is considered more satisfactory for heavy vehicles in hard service. Its capacity is limited and, when the air requirements are such that the accumulator is forced to work at full capacity continuously with a dirty engine, considerable carbon and oily sludge may be carried over into the system. A certain percentage of sulphuric and nitric acids are also present in the gas generated in this manner and must be taken into account on installations having heavy air-requirements.

Reservoirs are made from seamless drawn-steel shells, welded circumferentially, tin-coated inside and outside, and tested to an hydraulic pressure of 600 lb. per sq. in. The safety-valve ordinarily is adjusted to blow-off at 200 lb. per sq. in.

The control-valve may be either hand or foot-operated, as may be desired. Experience has indicated that the hand-operated valve is preferable for motor trucks and fire apparatus, while foot control is preferable on passenger cars and motorbuses. In motorbus service, the operator requires full use of his hands for collecting fares, making change, issuing transfers, operating doors, and the like. The operating principles of both valves are the same. A sectional view of the foot-operated valve is shown in the central view of Fig. 11. The regulating spring is mounted above and is supported by a thin sheet-metal diaphragm. The exhaust-valve is normally held open, and the inlet-valve is closed by spring pressure. These valves are controlled by a rocker-arm that fulcrums about a rounded pivot on the under side of the diaphragm.

When the valve is moved to the position of application, the regulating spring is compressed through a suitable cam in the hand-operated valve and directly in the foot-operated valve, and depresses the diaphragm, which, in turn, closes the exhaust-valve and opens the intake-valve. This admits air from the reservoir into the brake pipe and, when the pressure admitted is enough to lift the diaphragm and further to compress the regulating spring, the inlet-valve closes. The brake pressure is then balanced by the pressure of the regulating spring, which, in turn, is controlled by the position of the operating-lever. A further movement of the lever imposes still more force on the spring, and causes the balance to be established at a higher pressure; a movement of the lever toward the release position allows the diaphragm to lift and to open the exhaust-valve so that enough air is released to balance at a lower pressure.

With this type of valve, the brake-line pressure depends directly on the movement of the operating-lever; the farther the lever is moved from the release position, the greater will be the pressure that is established. An application of the brake may be graduated in pressure increments as fine as 1 lb., and graduated release in 2-lb. steps is possible. A flexible and sensitive graduating control-valve is most essential to the successful operation of the automotive airbrake equipment.

This type of valve will also maintain brake-line pressure against leakage up to the capacity of the valve. The maximum brake-line pressure is determined by the properties of the regulating spring, and is set normally at some pressure between 30 and 60 lb. per sq. in., depending on the conditions of installation. With the foot-valve, the maximum pressure may be varied by the adjusting-screw. The foot-valve is self-releasing through spring action; with the hand-valve, the application is maintained until the lever is moved to the release position.

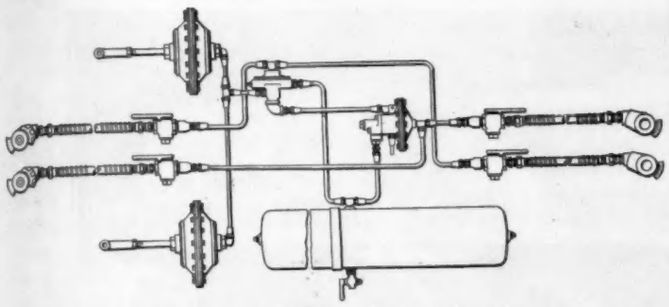


FIG. 14—PIPING FOR DOUBLE-END TRAILER
In Service-Brake Applications, the Trailer Brakes Are Applied Simultaneously and with the Same Intensity as Are the Truck Brakes

The conventional cylinder and piston have been discarded in favor of the brake chamber, shown at the right of Fig. 11, which consists of two dished plates, between which is a diaphragm made of special rubber-composition with fabric-layer inserts. Brake-pipe air is admitted to one side of the diaphragm; on the other side, a plate and a push-rod are connected to the brake rigging. No mechanical connection is placed between the plate and the diaphragm, the brake-release springs holding the plate firmly seated against the diaphragm. These brake chambers are made in diameters of from 5 to 11 in., to deliver the maximum push-rod forces of from 300 to 1500 lb. at 50-lb. per sq. in. brake-pipe pressure.

The normal working stroke of the brake chamber is from 0.75 to 1.50 in.; and the effective area of the diaphragm is approximately constant throughout this range, so that equalization is secured when the brake chambers act independently of each wheel.

When diaphragms are used instead of pistons, the brake chambers are entirely free from leakage without the use of packing and are free to respond to the slightest variation of pressure, a thing that cannot be said of small-diameter cylinders in which packing friction is a measurable factor. The brake chamber requires no maintenance or lubrication throughout the life of the diaphragm. Because of the gradual deterioration of rubber with age, it is recommended that diaphragms should be replaced yearly, although diaphragms that have been removed after 3 years of continuous service have been in first-class condition.

On truck and motorbus installations, a high-speed, continuous-duty air-compressor is substituted for the accumulator and, on hand-controlled equipments, in which the brake-valve is located at a considerable distance from the brake chamber, a relay valve or application release-valve is interposed between the brake-valve and the brake chamber. A diagrammatic truck and trailer installation is shown in Fig. 12. The brake-valve now controls only the volume of air in the pipe ahead of the application release-valve, and instantaneous application and release are assured.

In the application release-valve, Fig. 13, the chamber *A* in front of the diaphragm is connected with the brake pipe *B*, while chamber *C* behind the diaphragm, which also contains the exhaust slide-valve *D*, is connected with the brake chamber *E*. A pin-type inlet-valve is also connected with the intake-pipe from the reservoir *F*. The diaphragm is normally in such a position that the exhaust valve is slightly open, keeping the brake chamber connected with the atmosphere. When air is admitted to the brake pipe from the brake-valve, the diaphragm is deflected inwardly to close the exhaust-valve and to open the inlet-valve, thus allowing air to flow from the reservoir into the brake chamber. The inlet-valve closes when the pressure of the brake chamber builds up and becomes equal to that created in the brake pipe. When the brake-pipe pressure is exhausted by the brake-valve, the diaphragm is deflected forward the full amount, to open the exhaust and to release air from the brake chamber.

The equipment for a "reversible" trailer, with a drawbar attachment at each end, is shown in Fig. 14. The trailer reservoir is normally charged from the emergency pipe through the emergency valve; and, in service-brake applications, the trailer brakes are applied simultaneously and with the same intensity as are the truck brakes, through the brake pipe controlling the application release-valve on the trailer, and through open passages in the emergency valve. In case of an accidental separation of the truck and the trailer, both those lines to the trailer will be broken and the emergency valve will function automatically to apply the brakes of the trailer and to seal the open pipes against leakage. The brakes of the trailer are held in full application until released by the opening of the reservoir drain-cock. A sectional view of the emergency valve is shown in Fig. 15. In service-brake applications, the trailer reservoir *G* is charged by the pressure from the emergency pipe *H*, which passes around the diaphragm *I*, holding it depressed, sealing the valve *J*, and holding the valve *K* open for the free passage of air from the application release-valve *L* to the brake chamber *M*. When the emergency pipe is broken and its pressure is reduced, the diaphragm is lifted, sealing the emergency pipe *H* and closing the valve *K*, to prevent leakage through the brake pipe. At the same time, the valve *J* is open, and allows air to flow directly from the trailer reservoir *G* to the brake chamber *M*.

A typical truck-and-trailer installation is shown in Fig. 16, and a close-up of the truck installation, in Fig. 17. The gross load of this unit is 40,000 lb.

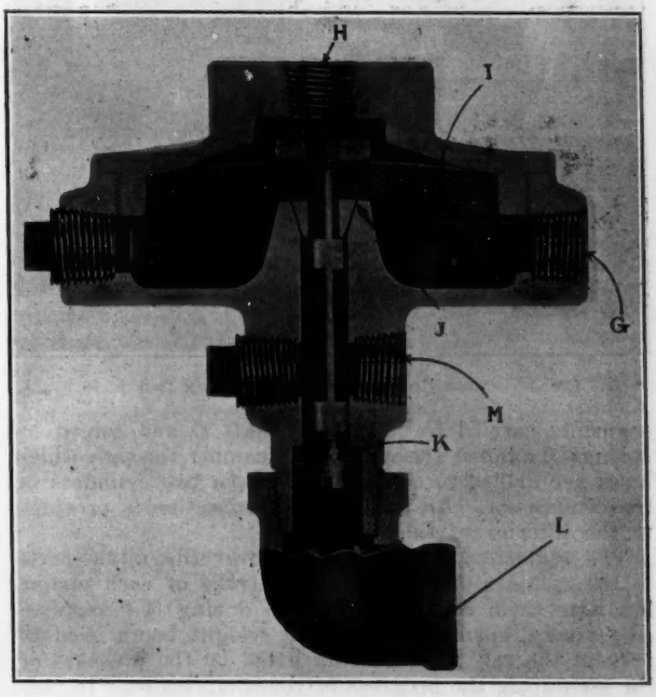


FIG. 15—EMERGENCY VALVE
In Case of Accidental Separation of the Motor Truck and the Trailer, the Emergency Valve Functions Automatically in Applying the Brakes

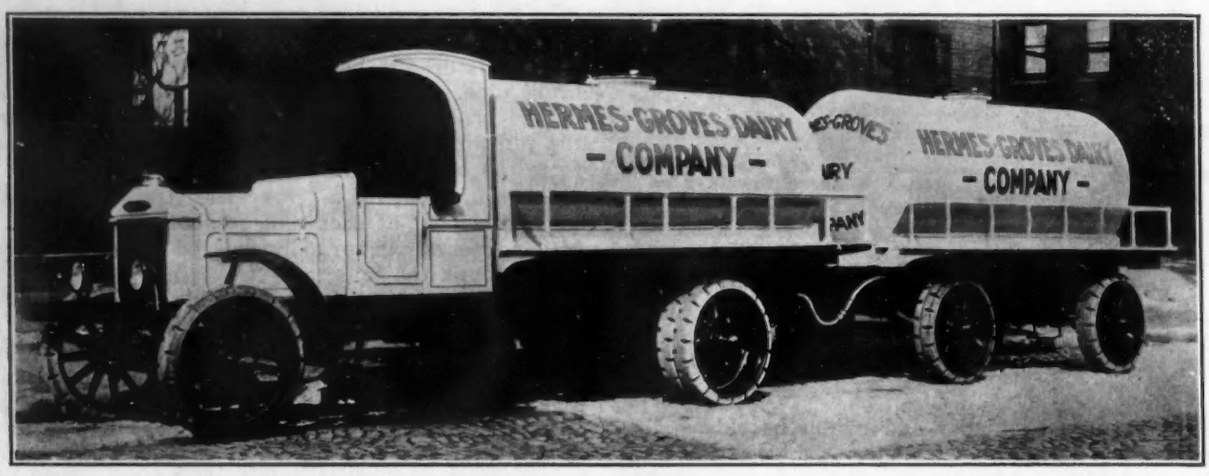


FIG. 16—TYPICAL TRUCK-AND-TRAILER INSTALLATION
The gross Load of This Unit Is 40,000 Lb.

The essential requirements of an air-compressor in automotive-brake service are reliability and light weight. These necessitate the use of a high-speed machine, so that the total piston-displacement per minute may be the maximum for the size determined upon. A positively driven or mechanically operated inlet-valve is necessary for satisfactory high-speed operation, for under these conditions the efficiency of any form of spring-loaded or automatic valve is very low because of its inertia and resistance to movement.

A transverse section of the type-B two-cylinder compressor is shown in Fig. 18. The inlet-valve *N* is very simple in construction, consisting merely of two brass

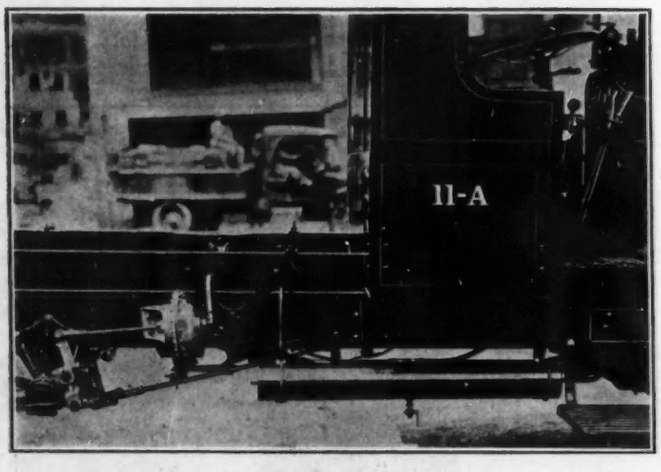


FIG. 17—CLOSE-UP VIEW OF TRUCK SHOWN IN FIG. 16

segments carried by a vertical shaft *O* and forced by springs *P* against the walls of a chamber through which holes are drilled to the interior of the two cylinders of the compressor. An atmospheric connection is provided to the interior of this chamber.

The segments, in rotating, uncover the intake-ports to the cylinder during the down stroke of each piston, but keep them completely covered during the compression stroke, springs of sufficient weight being used to prevent the valves from being lifted by the pressure of the air during the progress of the compression. In this valve, the volumetric efficiency actually increases slightly as the speed is increased up to 1800 r.p.m., and perfectly satisfactory operation is obtained even at 2400 r.p.m. The efficiencies are higher than those which are obtained with slow-speed machines, even of a much larger size.

Pressure oiling, by a geared oil-pump driven from the inlet-valve stem, is used throughout, every important bearing being included. The oiling system is protected against too high pressure by a relief-valve *Q*. To seal off the crankcase from the inlet chamber, and thus posi-

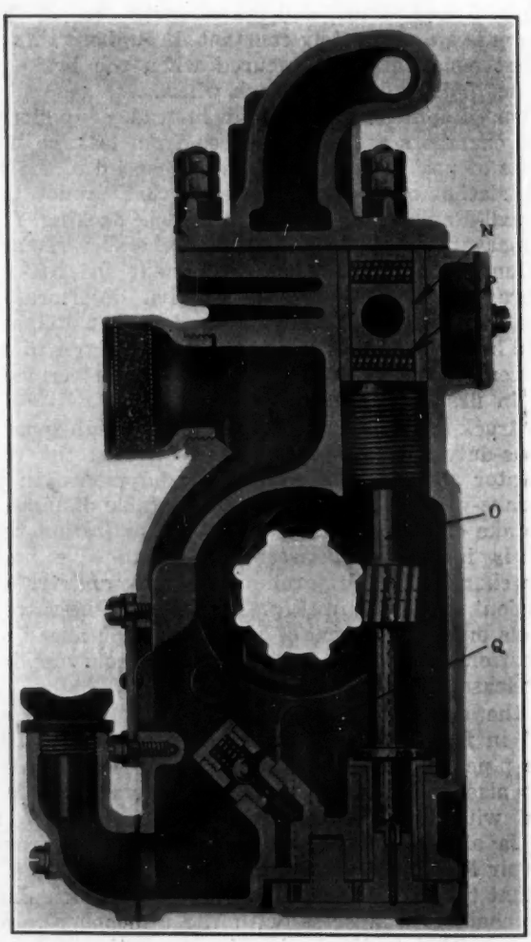


FIG. 18—SECTION OF TYPE-*B* TWO-CYLINDER COMPRESSOR
The Essential Requirements Are Reliability and Light Weight

tively ensure against the passing of the oil through the compressor, a special labyrinth seal is provided on the inlet-valve shaft.

A horizontal section showing the air passages through the inlet-valve is shown in the inset cut of Fig. 19, which also shows the longitudinal section. The crankshaft *R* and discharge valves *S* are made from heat-treated chrome-nickel steel. The crankshaft and connecting-rods *T* are drop-forgings. All the main bearings, connecting-rod bearings and the thrust bearings of the inlet shaft are babbitted. The two crankshaft end-bearings are interchangeable. The crankpin brasses are doweled to the connecting-rod cap and are easily assembled for replacement or adjustment with shims, by the use of which wear can easily be taken up.

The inlet-valve brasses, rotating in a circular chamber, are, to a large extent, self-lapping and require no attention whatever. The discharge valves are spring-weighted, with springs calculated to give proper action at high speeds and to prevent the valve from striking its cap on the compression stroke. Both the cylinders and the inlet-valve chamber are ground. At the present time, after endurance tests of several months, wear of all the parts is practically imperceptible.

This compressor is now manufactured in three sizes with displacements of 3, 6 and 12 cu. ft., respectively, at a rated normal speed of 1250 r.p.m. The 3-cu. ft. compressor, which has ample capacity for the braking requirements of passenger motorbuses, or of motor trucks and single trailer units, weighs slightly less than 21 lb. The 6-cu. ft. machine is recommended for motor truck and motorbus service in which other air-auxiliaries, in addition to the brakes, are included; and the 12-cu. ft. machine is especially adapted to rail-car service.

These compressors are, strictly speaking, continuous-duty machines, and are intended to be driven directly from the engine and to be operated whenever the engine is running, rather than from power obtained from the transmission, which, at best, is in a rather inaccessible location and subjects the compressor to sudden changes of torque during gear-shifting. Special provision for the compressor drive is included on many motorbus and motor-truck engines by the manufacturers.

The compressor ordinarily is independently oiled through its own crankcase, which has special provisions for filling with oil and for indicating the level of the oil in the crankcase. Oiling is required at approximately 1000-mile intervals. In special installations, provision is made for connecting a pressure line from the engine oiling-system directly with the compressor, so that lubrication is automatically provided without the necessity for filling the crankcase.

Governing is ordinarily accomplished by a pressure-regulator, or blow-off valve, set at approximately 75 lb. per sq. in., so that after this pressure has been attained in the reservoir, the excess air is discharged to the atmosphere. Under these conditions, the 3-cu. ft. machine requires 0.5 hp. at 1250 r.p.m. Any declutching type of governor involves mechanical complications; and unloading devices create a condition very favorable to oil's passing into the compression space. It is possible to govern these machines entirely by internal clearance, in which case a spacer-plate is inserted under the compressor-head, to introduce sufficient cylinder clearance so that the maximum compression-pressure will not exceed any predetermined value between 100 and 200 lb. per sq. in. Under these conditions, the reservoir pressure is built-up to the balancing pressure, at which point the compressor discharge is zero and the power requirement very low. The capacity of the machine at normal working-pressure, however, is reduced because of the introduction of clearance volume. Typical performance-curves for the 3-cu. ft. compressor are shown in Fig. 20. The temperature of the compressor in normal operation will be between the limits shown and depends upon the speed, the pressure, the cooling draft and other conditions of the installation.

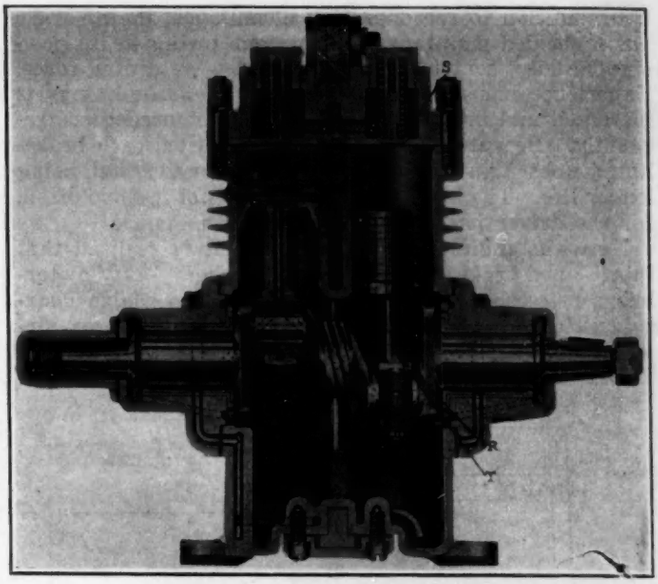


FIG. 19—HORIZONTAL AND LONGITUDINAL SECTIONS SHOWING AIR-PASSAGES THROUGH THE INLET-VALVE
Compressors Are Made in Three Sizes, Having Displacements of 3, 6 and 12 Cu. Ft., Respectively

A suitable suction air-strainer of the curled-hair type, or other form of dust-protector in the air-suction line, is specified for all compressor installations.

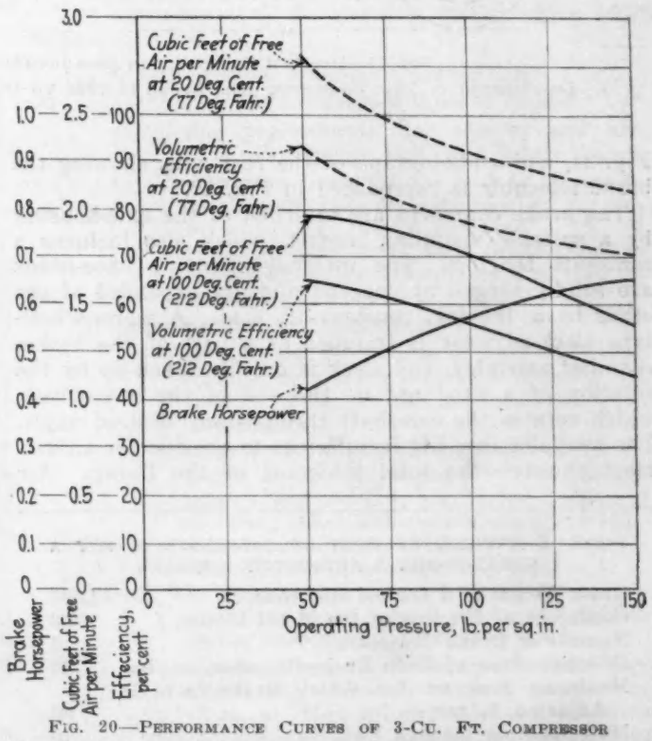

Cubic Feet of Free Air per Minute at 20 Deg. Cent. (77 Deg. Fahr.)
Volumetric Efficiency at 20 Deg. Cent. (77 Deg. Fahr.)
Cubic Feet of Free Air per Minute at 100 Deg. Cent. (212 Deg. Fahr.)
Volumetric Efficiency at 100 Deg. Cent. (212 Deg. Fahr.)
Brake Horsepower
3.0
1.0 2.5 100
0.9 90
0.8 2.0 80
0.7 70
0.6 1.5 60
0.5 50
0.4 1.0 40
0.3 30
0.2 0.5 20
0.1 10
0 0 0
0 25 50 75 100 125 150
Operating Pressure, lb. per sq. in.
Brake Horsepower
Cubic Feet of Free Air per Minute
Effeciency, per cent

FIG. 20—PERFORMANCE CURVES OF 3-CU. FT. COMPRESSOR
The Temperature of the Compressor in Normal Operation Will Be between the Limits Shown and Depends upon the Speed, Pressure, Cooling Draft, and Other Conditions of the Installation

In addition to the operating advantages, the airbrake has a decided maintenance advantage owing to its powerful easily controlled and equalized retarding-force. Experience has shown that the life of brake-linings is increased and brake adjustments are not needed so frequently. Because of automatic equalization, each brake-lining does its share of the work, the net result being longer life. The brakes are apparently not used so often, for the driver has greater confidence in them.

Notwithstanding these advantages, it is realized that fabric-lined brakes are inadequate for heavy-duty motorbus service, because of their inherently variable characteristics, consequently the development of an air-operated metal-to-metal brake was begun in 1922. A diagrammatic arrangement of the equipment is shown in Fig. 21, and a photograph of the rear axle, showing the brake assembly is reproduced in Fig. 22.

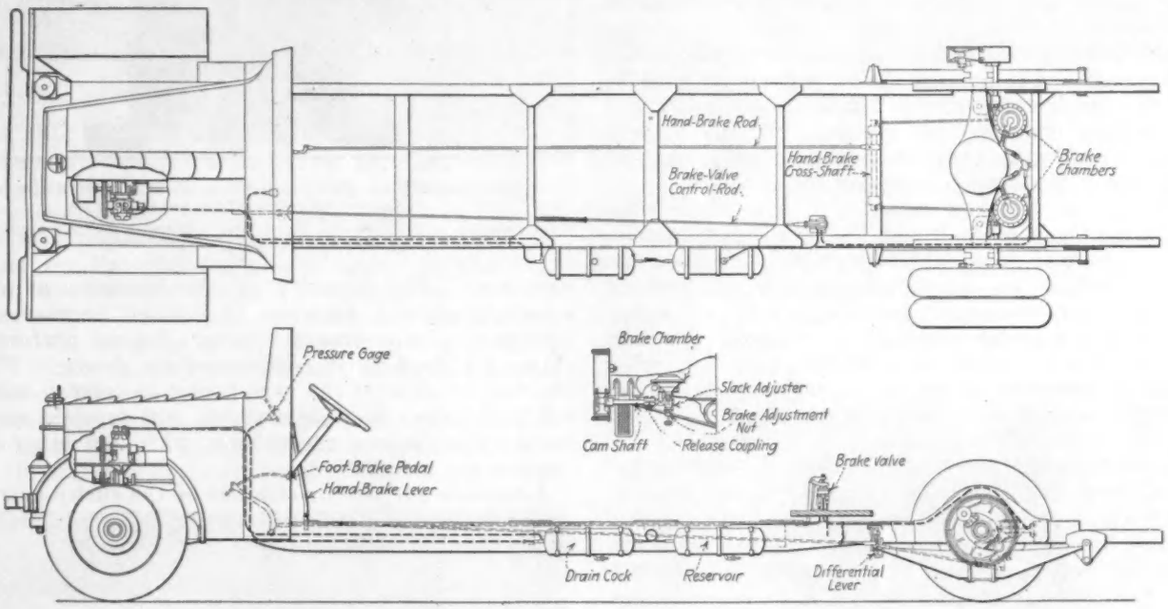


FIG. 21—DIAGRAM SHOWING THE ARRANGEMENT OF AN AIR-OPERATED METAL-TO-METAL BRAKE

Development of This Equipment Was Begun in 1922 To Overcome the Inadequacy of Fabric-Lined Brakes for Heavy-Duty Service

The brake chambers are attached to the axle-housing by a suitable mounting-bracket, which also includes a camshaft bearing. The internal-expanding shoe-heads are solidly hinged at one end and are expanded at the other by a 180-deg. constant-lift cam. A worm-wheel-type slack-adjuster is included as a part of the brake-chamber assembly, and slack is quickly taken-up by the rotation of a fixed nut on the end of the wormshaft, which rotates the camshaft through any desired angle. The available cam-lift is sufficient to provide for adjustment through the total thickness of the lining. Air connection to the brake chambers is made through flexible tubing anchored to the frame.

The hand-brake may be connected with the metal brake, but an entirely independent hand-brake attached to the propeller-shaft is preferable.

Metal brakeshoes $\frac{3}{8}$ in. thick are bolted to the brake-heads and cover an arc of approximately 90 deg. The brake-drum is also lined with a two-section metal liner, $\frac{3}{8}$ in. thick, bolted or riveted into place, as shown in Fig. 23. Ventilating ducts are provided to assist in cooling.

Calculations for the metal brake may be made on the basis of equations previously established, as illustrated by the typical example given in Table 1.

With rear-wheel brakes only, for the tire diameter of 36 in., a brake diameter of 18 in., and a condition of locked wheels,

$$M \text{ (cam force)} = 0.36\,W/fK$$
$$M \text{ (total)} = 60 \times 25 \times 10 \times 2 \times 0.8 = 24{,}000 \text{ lb.}$$
$$0.36\,W/fK = 0.36 \times 14{,}000\,/0.2 \times 1.115 = 22{,}600 \text{ lb.}$$

It is apparent that, with the maximum application of the brakes, the braking force will be more than sufficient to take advantage of the maximum road-adhesion and, with the above conditions existing, the brake will be sufficiently powerful to lock the wheels of the fully loaded motorbus on a dry level road having an adhesion coefficient of 0.6.

The shortest possible stop is made when the wheels are rolling but are just at the point of locking; the flexibility of the brake-valve allows the driver to control the action of the brake to any desired degree of intensity. By the brake-valve adjustment for the maximum brake-line pressure, the braking power may be regulated to suit the particular conditions surrounding any installation.

During development work with the metal brake, experimental brakeshoes and drum-liners were made from supposedly ordinary 0.20 per cent carbon hot-rolled mild-steel plates. The first commercial installations were

TABLE 1—TYPICAL EXAMPLE OF CALCULATIONS FOR A METAL-TO-METAL AUTOMOTIVE AIRBRAKE

Gross Weight of a Loaded Motorbus, lb.	14,000
Coefficient of Friction of the Metal Lining, f	0.2
Number of Brake Chambers	2
Effective Area of Each Brake-Chamber, sq. in.	25
Maximum Pressure for Which Brake-Valve Is Adjusted, lb. per sq. in.	60
Multiplication through Cam	10
Efficiency	0.8
K for 90-Deg. Brake-Shoe	1.115

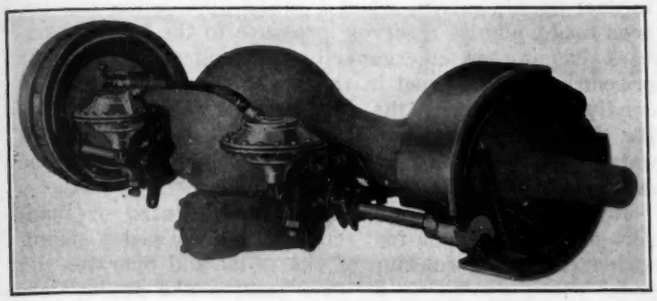


FIG. 22—BRAKE ASSEMBLY OF REAR AXLE
The Brake Chambers Are Attached to the Axle-Housing by a Suitable Mounting Bracket

made in January, 1923, on 11 Fageol coaches that were being operated in street-car service by the Puget Sound International Railway & Power Co. at Everett, Wash. The same cars with fabric-lined rear-wheel service-brakes had previously averaged 3000 miles between lining renewals and 15,000 miles between drum renewals. After the installation of the metal brake-equipment, the life of the brakeshoes averaged 15,000 miles, which meant more than 64,000 full stops from a speed of 20 m.p.h. on cars averaging more than 14,000 lb. total weight. The life of the drum-liners averaged approximately 50,000 miles. With such results as this, the problem of suitable lining-material had apparently been solved. Later results, however, with mild steel obtained from different sources of supply, failed to show the same consistent performance, and a series of tests is now in progress to establish definite specifications for the most suitable lining-material.

The verified figures from the operation of the Key System Transit Co., Oakland Cal., presented in Table 2 are typical of the results obtained.

These motorbuses are operated in a service that normally imposes very severe braking conditions. Air service-brakes and manual holding-brakes are both connected to the same set of metal brakeshoes so that the

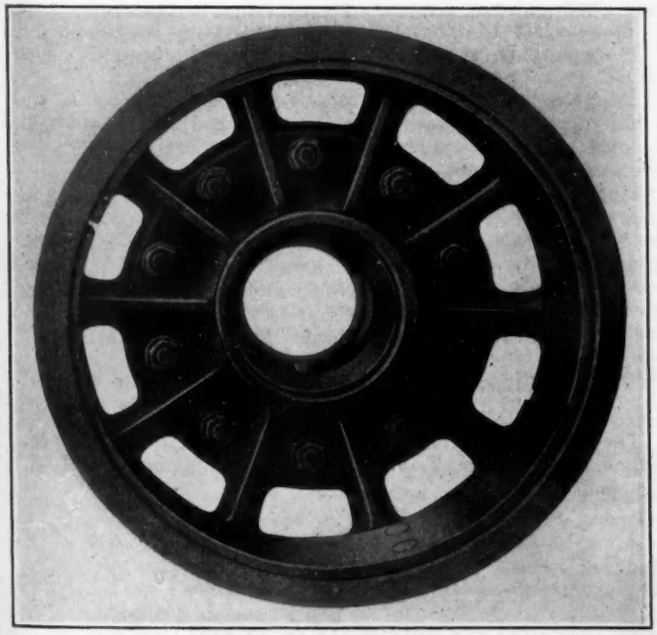


FIG. 23—VIEW OF BRAKE-DRUM WITH TWO-SECTION METAL LINER
Metal Brakeshoes ⅜ In. Thick Are Bolted to the Brake-Heads and Cover an Arc of Approximately 90 Deg. Ventilating Ducts Are Provided To Assist in Cooling

TABLE 2—COMPARATIVE DATA ON FABRIC AND METAL BRAKES

Street-Car-Type 29-Passenger Motorbus, Normal Weight, Loaded, lb.	14,000
Average Speed, Including Stops, m.p.h.	15
Length of Run, miles	1.76
Total Number of City Blocks	21
Average Number of Complete Stops per Mile	8
Average Life of Fabric Linings on Rear-Wheel Service-Brakes, miles	3,500
Average Distance between Brake Adjustments, with Metal Brakes, miles	6,000
Average Total Number of Complete Stops between Brake Adjustments with Metal Brakes	48,000
Average Total Life of Metal Brakeshoes, miles	30,000
Average Total Number of Stops during the Life of Metal Brakeshoes	240,000
Average Life of Metal Drum-Liners, miles	75,000

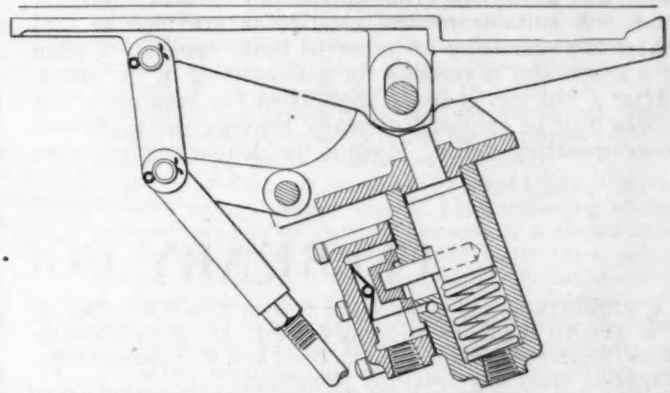


FIG. 24—SPECIAL PEDAL FOR CONTROLLING THE ENGINE THAT PNEUMATICALLY OPERATES THE DOORS
Acceleration Is Secured by Depressing the Ball of the Foot, and Application of the Brakes Is Graduated by Depressing the Heel

actual braking-service imposed is comparable to that on both hand and foot-brakes on ordinary fabric-lined mechanical systems.

The advantages of air-operated metal-brakes briefly summarized are:

(1) Greatly reduced brake-maintenance costs
  (*a*) Lining life is increased three to tenfold
  (*b*) Lining replacements are cheaper and are made more quickly than with fabric linings
  (*c*) The earning power of the unit is increased, for the total time per year required for lining renewals is greatly decreased
  (*d*) Periodic replacement of worn brake-drums is eliminated, as the drum-liners that take up the wear are renewable

(2) Greater safety and reliability
  (*a*) The coefficient of friction between the metal surfaces in braking contact is constant, regardless of the conditions of moisture or of temperature
  (*b*) The braking ratio is constant and is not affected by the adjustment of the linkage, toggles, and the like, nor by the friction of the pins, yokes and connections of an ordinary brake-linkage system
  (*c*) Brake adjustment is simple and positive
  (*d*) The operator is relieved from all fatigue accompanying the use of mechanical brakes and is more alert for his other duties

(3) Greater average-speed and decreased maintenance on other units. Because of their satisfactory operation at higher temperatures and their greater heat-radiating ability, the vehicle may safely be kept in high gear even on long mountain down-grades, while maintaining a higher

speed and being free from crankcase oil-dilution and the other evils that accompany the use of the engine as a brake in low gear

The motorbus in street-car service will shortly be classed as a common carrier and will be subjected to the legislation that governs the equipment and operation of street-cars. This has been anticipated by the development of a safety interlocking equipment that parallels very closely the features of the one-man Birney safety-car of which some 14,000 are in operation on traction properties today.

The doors are operated by a suitable pneumatic-door engine and are controlled by a small four-way valve on the dashboard. The special operating-pedal is illustrated in Fig. 24. This pedal is in the form of a treadle, acceleration being secured by depressing the ball of the foot, and graduated brake-application by depressing the heel. A suitable neutral position is provided so that there is no tendency for a partial brake-application when the accelerator is released for gear-shifting or for idling. After a full service-brake application has been made, the doors may be operated normally through the pneumatic door-operating valve. Moving the door-operating valve to door-open position, when a brake application has not been made, admits reservoir pressure to the brake chambers, causing an emergency-brake application; and air pressure is maintained in the brake chambers under all conditions so long as the door valve is in the door-open position. This means that the doors cannot be opened until a full brake-application has been made, nor can the car be started while the doors are open.

In case the operator becomes incapacitated or inadvertently removes his foot from the control pedal, spring action raises the fulcrum of the pedal and operates the pedal valve, producing an emergency-brake application, and at the same time balancing the door engine so that the doors may be pushed open by hand. Provision can also be made to disengage the clutch pneumatically to avoid the possibility of damage to the transmission system. This is known as the "deadman application" feature.

The paramount requirements of a perfect brake are consistent performance, long life, adequate braking-power, ease and flexibility of control and the maximum-safety features. The object of this paper is to show how the airbrake meets these requirements.

FEBRUARY COUNCIL MEETING

A SESSION of the Council was held in New York City on Feb. 26, the following being present: President Horning, Vice-Presidents Carlson, Church, Scott and P. G. Zimmerman, Councilor Hunt and Treasurer Whittelsey.

Thirty applications for individual membership were approved. The following transfers in grade of membership were made: From Associate to Member, G. E. Denis, C. R. Paton, W. J. Spiro and C. A. Winslow; from Junior to Member, A. R. Hopkins; from Junior to Associate, C. H. Grill and G. F. Michael; from Member to Foreign Member, Valdemar Cronstedt, and from Member to Service Member, T. L. Blakemore and H. T. Rendall.

The resignations of six members were accepted. Two members who had been dropped from the roll of membership were reinstated.

Detail plans of the meetings of the Society to be held this year were considered.

The following were appointed to serve on the Standards Committee, with assignment to divisions as indicated:

R. I. Dick—Agricultural Power Equipment Division
W. P. Louden—Electrical Equipment Division
S. H. Caldwell—Frames Division
E. P. Pearson—Passenger-Car Body Division
W. J. Baumgartner—Truck Division

L. N. Ericksen was added to the personnel of the Hardwood Lumber Standardization Committee.

The following subjects were assigned to the Standards Committee:

Isolated electric lighting-plant generator specifications—Isolated Electric Lighting-Plant Division

J. F. Winchester was appointed a member of the Highways Committee of the Society.

The appointment of A. H. Jameson and J. E. McCauley to serve as the representatives of the Steel Founders Society of America on the Sectional Committee on Numbering of Steel was approved.

It was reported that the Illuminating Engineering Society had designated the following as its representatives on the Sectional Committee on Motor-Vehicle Lighting: J. H. Cattell, E. H. Hobbie, W. F. Little, L. C. Porter and C. H. Sharp. The Society of Automotive Engineers, which jointly with the Illuminating Engineering Society is sponsoring this Sectional Committee, also has designated five representatives. In addition, the following organizations are represented on the Committee as indicated below:

R. E. Carlson	American Automobile Association
E. C. Crittenden	Bureau of Standards
William T. Davis	International Association of Chiefs of Police
Alfred W. Devine	Conference of Motor-Vehicle Administrators
A. W. S. Herrington	War Department
Russell Huffman	Motor-Vehicle Conference Committee
Walter G. King	National Safety Council
Dean J. Locke	American Electrical Railway Association
H. H. Oetjen	Motor and Accessory Manufacturers' Association
Walter S. Paine	National Bureau of Casualty & Surety Underwriters
T. D. Pratt	Motor Truck Association of America
G. H. Stickney	American Institute of Electrical Engineers

The Society's representatives on the Committee are H. M. Crane, R. N. Falge, T. J. Litle, Jr., C. A. Michel and A. J. Scaife.

Vol. XVI March, 1925 No. 3

Recent Developments in Aircraft Engines

By L. M. WOOLSON[1]

ANNUAL MEETING PAPER *Illustrated with* PHOTOGRAPHS AND DRAWINGS

ABSTRACT

ADVANCES in airplane performance during the last few years may be ascribed mainly to advances in aerodynamics and to improvements in powerplants. The latter have resulted in producing more power for the same weight of engine and smaller overall dimensions for engines of the same power-rating. The accompanying paper describes two engines of 500 and 800 hp. respectively that have been recently developed by the Packard Motor Car Co. for aircraft service. When these engines are compared with previous types they are found to be more compact and to produce more power per pound of weight. When each is operated at its rated speed, the Model 1500 engine develops 100 hp. more than the Liberty while weighing 140 lb. less, and the Model 2500 engine develops 250 hp. more than its predecessor, the Model 2025, with a decrease in weight of 75 lb.

In applying these facts to commercial aviation, these comparative performances mean that the new engines can carry double the pay-load over the same distance or the same pay-load 2¼ times as far as could their progenitors.

These improvements have been made possible largely because of a new type of cylinder construction, original studies with regard to the loads that can be carried by bearings, reduction of the weight of the crankshaft while at the same time strengthening it, and the compacting and lightening of the timing and accessory-drive layout. Other improvements were made in the lubricating system and in the design of the valve-gear and springs.

Nothing was taken for granted and every detail was given the closest scrutiny. It was decided that if a distinct advance in the art was to be made, it could be accomplished only by disregarding precedent and starting at the ground. As a result of investigating the relation of bearing materials to allowable speeds and loads, it was ascertained that failures of aircraft bearings rarely occur because of lack of lubrication or of wear but are caused by fatigue of the babbitt lining produced by minute flexing of the back of the bearing. Tests showed that the limitations of the bearings could be raised provided they could be prevented from flexing under load and ample force-feed lubrication were provided. The *PV* values of the bearing loads adopted, as compared with those of the Liberty engine, are: for the crankpin, 18,520 lb. per sq. in. as against 13,200; for the center bearing, 35,000 as against 22,650; and for the intermediate bearing, 27,000 as against 14,000.

The critical speed of vibration of the Packard crankshaft is 64 per cent higher than that of the Liberty; it is also twice as stiff as well as weighing 30 per cent less, a feature accomplished by the use of journals having comparatively large outside diameters but bored out through their centers.

Novel cylinder construction enables the cylinders to be spaced closely together and the weight of the whole engine to be diminished. Other advantages incorporated into the design include water circulation in close contact with the heated surfaces, the use of a steel cylinder-barrel as a wearing surface that carries the explosion loads down to the crankcase, the locating of the hold-down flange some distance from the end of the cylinder barrel so that the ends of the barrels of the cylinders of the two banks can practically be allowed to touch inside the crankcase and the engine can be run in an inverted position.

Still other features comprise improved types of valve-housing and valve-gear layout; positive cooling of the exhaust-valve by oil pumped through it; a special type of multiple-cluster small-diameter piano-wire valve-spring; simplicity in the grouping of the accessories; a special type of magneto having a single magnetic circuit and two independent electrical circuits, either one of which will fire all 12 cylinders; the possibility of replacing magneto ignition with battery ignition by substituting a generator for the magneto but without other change to the engine or to the wiring between the distributors and the spark-plugs; the use of very short comparatively light rugged slipper-type pistons; and the ability to use either direct drive or gear reductions.

As each improvement in engine design means an immediate improvement in airplane design, recent developments in engine design have already made possible maneuvers that would have been impossible a few years ago. Although experimental work is continually being directed along conventional lines, such as the barrel and cam types of engine and those of the Diesel or the semi-Diesel type, the most important advances, in the opinion of the author, are to be made by conventional 12-cylinder water-cooled engines and by 9-cylinder fixed-radial air-cooled engines.

When the weight of airplane engines is reduced to 1 lb. per hp., as seems likely in the near future, the engine will consume its weight of fuel every 2 hr. It is important, therefore, that, as the carrying capacity of the airplane is reduced by the amount of fuel that must be carried, efforts to reduce the fuel consumption should run concurrently with those to improve the engine.

THE wonderful improvement in airplane performance that has taken place during the last 6 or 7 years has been mainly due to two factors, (*a*) advances in aerodynamics that have improved the structure of the airplane and have decreased the parasitic resistances so that less power is required to fly at a given speed with a given load, and (*b*) improvements in powerplants that have resulted in producing more power for the same weight of engine, and smaller overall dimensions for engines of the same power-rating.

As an example of these powerplant improvements, I would call your attention, in Fig. 1, to a comparison of the Liberty engine with one of the new Packard engines that will be described later. It will be noted that the new engine is somewhat more compact than the Liberty,

[1] M.S.A.E.—Aeronautical research engineer, Packard Motor Car Co., Detroit.

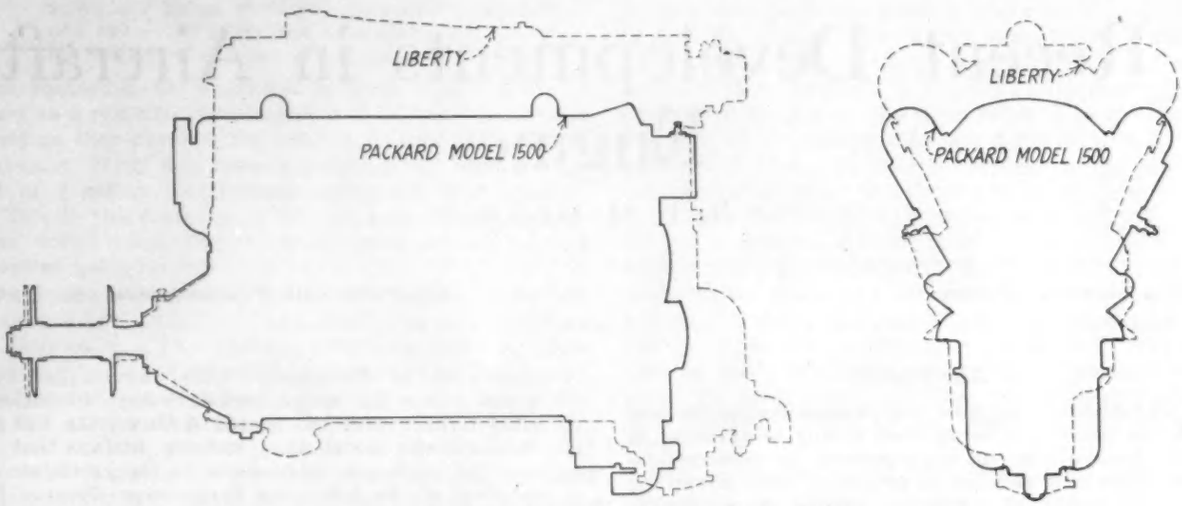
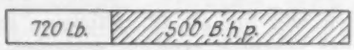
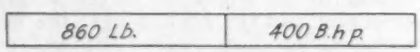


FIG. 1—PROFILES OF LIBERTY AND MODEL 1500 ENGINES
The New Engine Is Somewhat More Compact, Particularly with Regard to Height and Length

particularly with regard to height and length. Bearing this in mind and examining Fig. 2, we find that the new engine develops about 100 hp. more than does the Liberty, when each is operated at its rated speed, and that the new 500-hp. engine weighs about 140 lb. less than the Liberty. A similar comparison in Fig. 3 shows





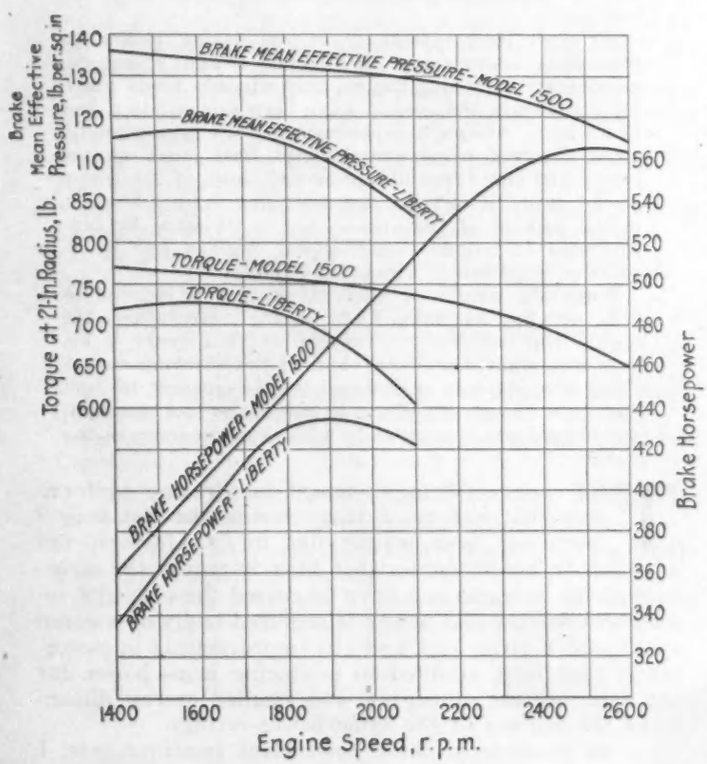
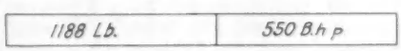


FIG. 2—COMPARISON OF WEIGHTS AND HORSEPOWERS OF THE LIBERTY AND THE MODEL 1500 ENGINE

When Both Engines Are Operated at Their Rated Speeds, the Model 1500 Engine Develops about 100 Hp. More and Weighs about 140 Lb. Less than the Liberty



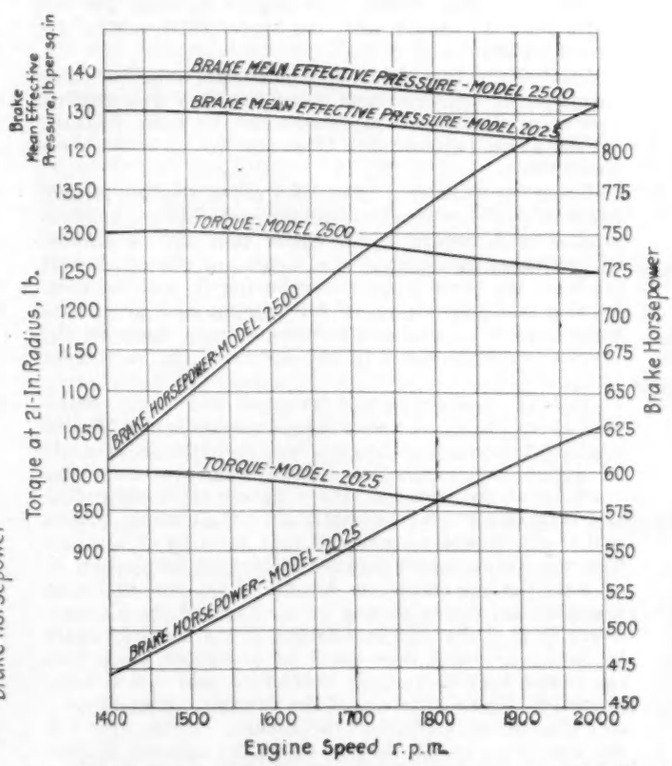


FIG. 3—COMPARISON OF WEIGHTS AND HORSEPOWERS OF THE MODEL 2025 AND THE MODEL 2500 ENGINE

The Model 2500 Develops 250 Hp. More than the Model 2025 Although Weighing 75 Lb. Less

the relative performance of the new 800-hp. engine and its predecessor, the Packard Model 2025 engine.

It will be of interest to translate these superiorities into airplane performance so that we may obtain a concrete impression of the advantages accruing to airplanes from the use of lighter and more compact engines. Actual flight tests with the new engines have so far been limited to some new military airplanes, the performance

of which I am not at liberty to disclose. But, as we all are working toward the development of commercial aviation as the ultimate goal, it will to a certain extent be even more interesting to examine the influence of lightweight powerplants on airplanes that have been designed for strictly commercial purposes.

With this in mind, I have prevailed on W. B. Stout, who is undoubtedly the foremost exponent of commercial aviation in this country if not in the world, to allow me to present comparative data on the performance of his Air Pullman when equipped with a Liberty and with a Packard Model 1500 engine. The data prepared by Mr. Stout's engineer, Mr. Prudden, are shown in Table 1 and, I am sure, will be of more than passing interest to students of commercial aviation. The comparison has been arranged in two ways: (*a*) on the assumption that the increased power and decreased weight of the new engine would be utilized to increase the pay-load without increasing the cruising radius, and (*b*) an alternative basis, that the improved performance of the new engine would allow the carrying of a greater fuel-supply to allow a greater cruising-range with the same pay-load as formerly.

TABLE 1—ESTIMATED COMPARATIVE PERFORMANCES OF THE STOUT AIR PULLMAN WHEN EQUIPPED WITH LIBERTY AND WITH PACKARD MODEL 1500 ENGINES RESPECTIVELY

	Liberty	*Model* 1500
Pay-Load, lb.	1,000	2,000
Useful Load, lb.	2,000	3,000
Cruising Radius with 1,000-Lb. Pay-Load, hr.	4	8½
Cruising Radius with 1,000-Lb. Pay-Load, miles	420	960
Cruising Radius with 2,000-Lb. Pay-Load, hr.	....	4
Cruising Radius with 2,000-Lb. Pay-Load, miles	....	440
Maximum Speed, m.p.h.	116	124
Cruising Speed, m.p.h.	105	112
Minimum Speed, m.p.h.	54	59
Climb from Sea Level, ft. per min.	600	700
Service Ceiling, ft.	10,000	11,000
Absolute Ceiling, ft.	12,000	12,700

Commercial Application

The first comparison shows that it is possible to transport double the pay-load over the same distance at a higher speed with the new engine than with the Liberty, and the second, that it is possible to transport the same pay-load over 2¼ times the distance at a higher speed.

The importance of these conclusions cannot be overestimated in the face of the oft-repeated statements to the effect that, although the development of lightweight aircraft engines is highly important for military aircraft, commercial aircraft can get along with comparatively heavy engines.

Here is an example of a 100-per cent increase in pay-load, or a possible 100-per cent increase in revenue, accomplished by substituting the new engine for the Liberty engine, itself as light as any aircraft engine used in commercial service today. And it should be remembered that aircraft-engine development of the present type has by no means reached the limit of its possibilities, nor are lightweight engines, when properly designed, more expensive to manufacture, less reliable, or shorter lived than so excellent an engine as the Liberty. The reverse is actually the case, for Government testing requirements for new engines are continually becoming more arduous, a highly commendable condition.

Before designing the new Packard engines, a definite program was laid down that differed somewhat from the course generally pursued in such cases. It had been decided that the new engines were to represent a distinct advance in the art, and the Packard organization had a background of experience in building aircraft engines that warranted setting a very high standard. The result could not be accomplished merely by making changes and improvements in an existing design; it was necessary to start at the ground and to disregard precedent when precedent was based on so-called common practice unsupported by well recognized and proved engineering limitations.

Study of Details

In other words, practically nothing was taken for granted. Even relatively unimportant parts of the en-

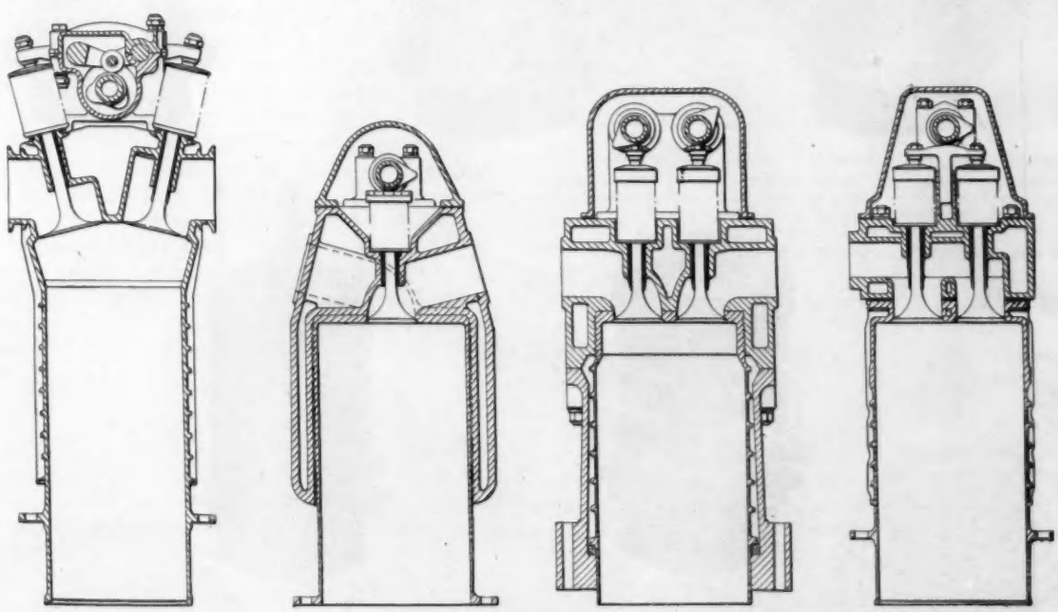


FIG. 4—A STUDY IN CYLINDER CONSTRUCTION
At the Extreme Left Is the Liberty Cylinder; the Two Central Views Show the Aluminum-Block Construction with Dry and Wet Sleeves Respectively; at the Extreme Right Is the New Steel Cylinder

gine received the closest possible scrutiny in an effort to obtain the maximum possible power-output with the least possible weight and the greatest possible dependability. Time will not allow an explanation of the methods employed in all cases but, in general, it may be stated that when a problem involved stresses that would yield to sound engineering methods, such a solution would be acceptable, but, when the design had been dictated merely by so-called good engineering practice, a more or less thorough investigation was made either by theoretical analysis, or by practical experimentation, or by a combination of the two, in an endeavor to ascertain the actual limitations.

A case in point is the matter of the relation of bearing materials to allowable loads and speeds. This, of course, represents one of the oldest studies in the world of mechanics; volumes have been written on it. The arrival of aircraft engines, however, has thrown an entirely new light on the possibility of increasing the permissible speeds and loads, provided that certain essential requirements that have been uncovered by long experience with aircraft engines are observed. At this point it might be well to inject the statement that the foundation of any engine design is represented by its bearing layout, that the structure cannot proceed until this foundation has been laid, and that the structure will not be satisfactory if the foundation is poor. In other words, a fundamental principle of good engine-design is, to begin with exact knowledge of the loads to which the engine bearings are to be subjected and to design accordingly.

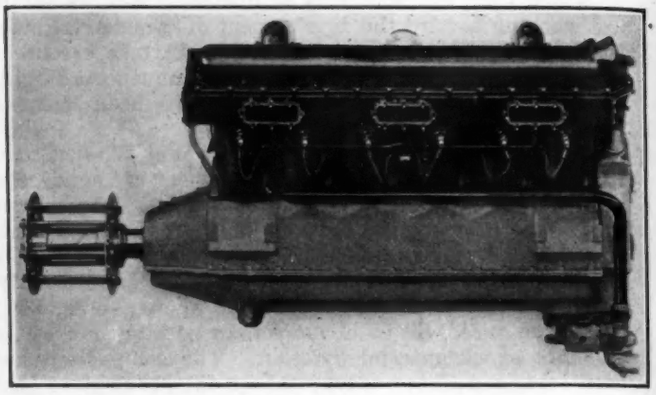


FIG. 6—RIGHT SIDE VIEW OF THE MODEL 1500 DIRECT-DRIVE ENGINE
The Cylinders Are Placed Very Close Together and the Valve-Housing Is Very Compact and Clean

In aircraft engines, the life of the connecting-rod and the main bearings are the most important influences controlling the period between overhauls and should receive first consideration. On the other hand, if past practice is merely followed and a so-called generous bearing-area is provided, we shall be overlooking two important considerations. One is that past practice in aircraft-engine bearings has not given altogether satisfactory results, the other, that we shall be prevented from using an im-

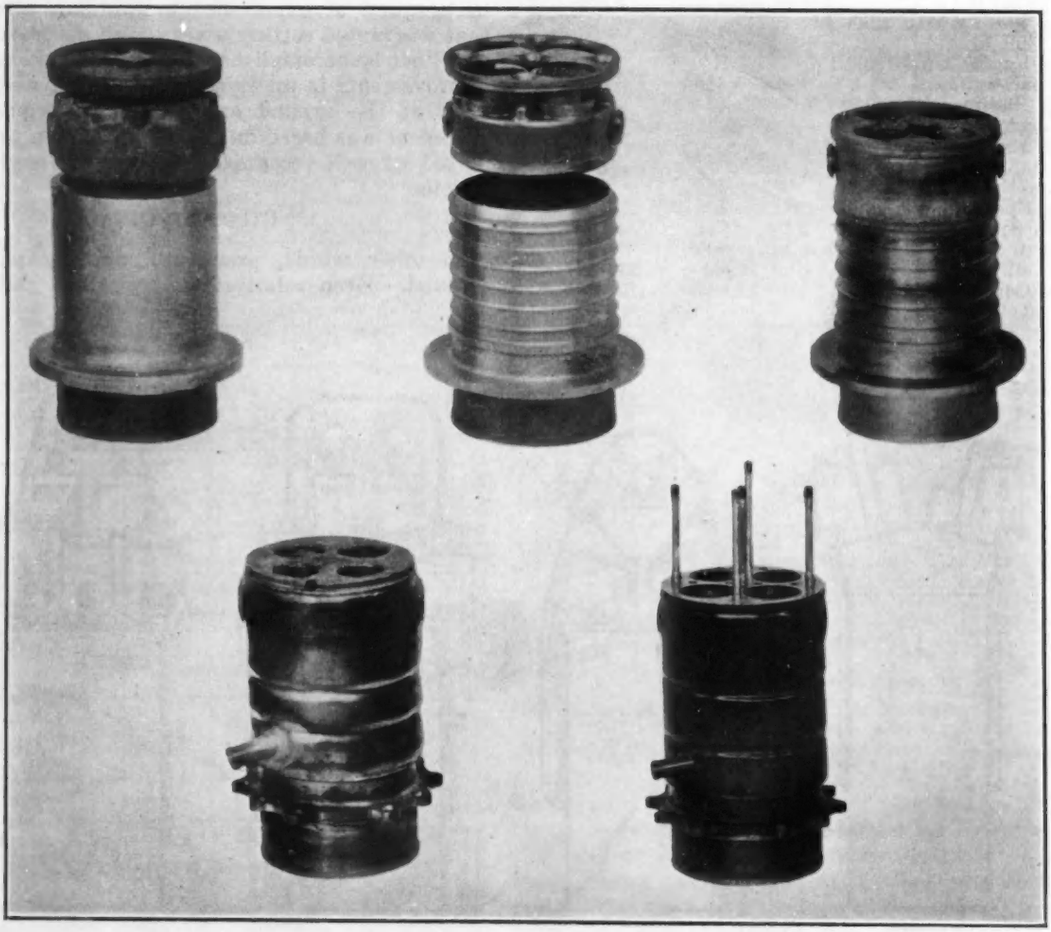


FIG. 5—FIVE STAGES OF STEEL CYLINDER CONSTRUCTION
The Weight of the Model 1500 Cylinder Is 9.5 Lb. and It Develops 50 Hp.; the Weight of the Model 2500 Cylinder Is 15.2 Lb. and It Develops Nearly 70 Hp.

TABLE 2—SUMMARY OF BEARING-MACHINE TEST RESULTS

Shaft Material	Bearing Material	Bearing Size Diameter, In.	Bearing Size Width, In.	Total Load, Lb.	Load, Lb. per Sq. In.	Speed Without Seizure, R.P.M.	*PV* Value Without Seizure, Lb-Ft. per Sec.
40-Point Carbon	Babbitt-Lined, Steel-Backed	1¾	¾	6,050	2,300	2,750	48,500
40-Point Carbon	Babbitt-Lined, Steel-Backed	1¾	1¾	12,100	1,975	2,950	44,500
40-Point Carbon	Half and Half Solder, Bronze-Backed	1¾	1¾	9,625	1,570	2,500	30,000
Hardened Steel	Phosphor Bronze	1¾	1¾	11,000	1,800	2,000	27,400
40-Point Carbon	71½ per cent Copper, 23 per cent Lead, 5½ per cent. Tin	1¾	1¾	8,030	1,310	2,000	20,000
40-Point Carbon	87 per cent Magnesium, 13 per cent Copper	1¾	1¾	6,050	990	2,000	15,000

Comparison of Loads and Bearing-Values of Liberty and Packard Model 1500 Engines

Ratings

Liberty.....420 b. hp. at 1700 r.p.m.
Packard Model 1500.....500 b. hp. at 2100 r.p.m.

	Bearing Loads					
	Crankpin		Center		Intermediate	
	Liberty	Model 1500	Liberty	Model 1500	Liberty	Model 1500
Maximum Unit Load, lb. per sq. in.	1,035	1,191	1,580	1,692	1,150	1,685
Mean Unit Load, lb. per sq. in.	750	808	1,365	1,274	720	983
PV, lb-ft. per sec.	13,200	18,520	22,650	35,000	14,000	27,000

portant means of reducing the weight, namely, reducing the length of the bearings and, consequently, the length of the engine. It will be necessary to digress for a moment to state that the length of an aircraft engine has not always been limited by bearing considerations for, in many cases, the closest spacing of cylinder centers possible with certain types of cylinder construction, rather than the length to be allotted to the bearings, has dictated the design.

Failure of Bearings

This limitation of close cylinder-spacing, however, was removed in the new Packard engines by a new type of cylinder construction and assembly that will be described later, hence, the necessity arose for a thorough investigation into the possibility of shorter crankshaft and connecting-rod bearings than had hitherto been customary.

Reverting now to the discussion of bearings, bearing failures had been observed in practically all makes and types of aircraft engine. These failures, however, were rarely caused by lack of lubrication, nor was the wear of the bearings measurable. Cracking and crushing of the babbitt was the major difficulty; and this occurred after from 30 to 150 hr. of operation, depending on the severity of the service.

Failures were finally found to be caused by fatigue

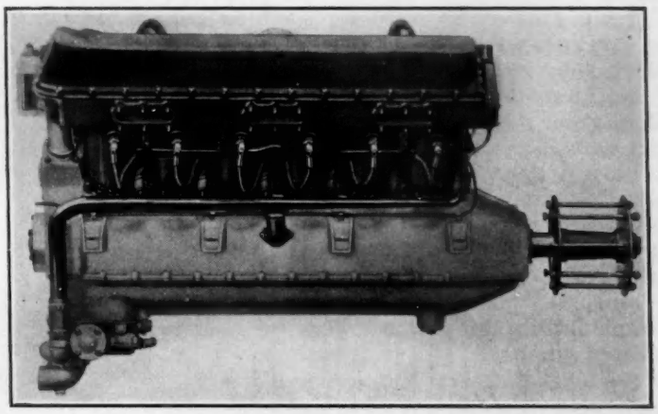


Fig. 7—Left Side View of Model 2500 Direct-Drive Engine
Its Similarity to the Model 1500 Engine Is Apparent. All the Features Described Are Common to Both Engines and in Some Instances the Parts Are Interchangeable

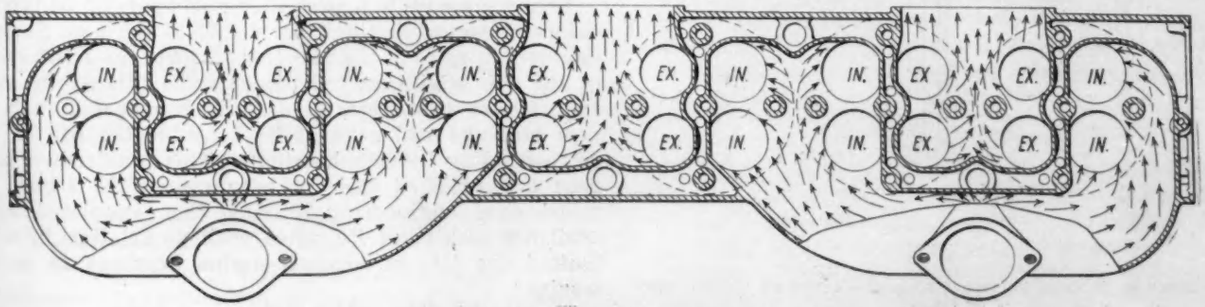


Fig. 8—Cross-Section of Valve-Housing, Showing Intake, Exhaust and Water Passages
The Large and Free Passages Are Obtained by Siamesing the Four Valves into One Port

of the babbitt lining that was produced by minute flexing of the backing of the bearing. The importance of more rigid bearing-backing was thus emphasized and it became evident that, if the babbitt were prevented from flexing under load, far greater loads could be carried without distress. It was then determined to run a series of tests on a bearing-testing machine, using various types of bearing-metals, and in each case gradually increasing the speed and the load in an endeavor to ascertain what the bearing limitations actually were, granted that the two well-recognized requirements were complied with.

Requirements of Bearings

The first of these was, that the bearing must not flex appreciably under load, and the second was, that ample force-feed lubrication must be provided, not only to produce a continuous oil-film, but also to circulate a quantity of oil sufficient to ensure the proper viscosity of the oil that maintains the requisite thickness of the oil-film.

It was realized that, in the engines to be built, both these requirements could be controlled in the design and, once the comparative information had been obtained from the bearing-machine tests, the data could be translated into the engine design. It was recognized, of course, that conditions in the bearing-testing machine were very different from those obtaining in an engine running under its own power, in that the loads on the machine were concentrated uniformly in a fixed direction, whereas those on the engine are constantly changing, both in intensity and in direction. It is not claimed that the results of these tests throw any particularly new light on the subject of bearings. What was accomplished was the acquiring of definite knowledge along the desired lines without having to rely on the reported work of various investigators, each of whom conducted his tests with other apparatus, other materials and other test-conditions of speed, load and lubrication.

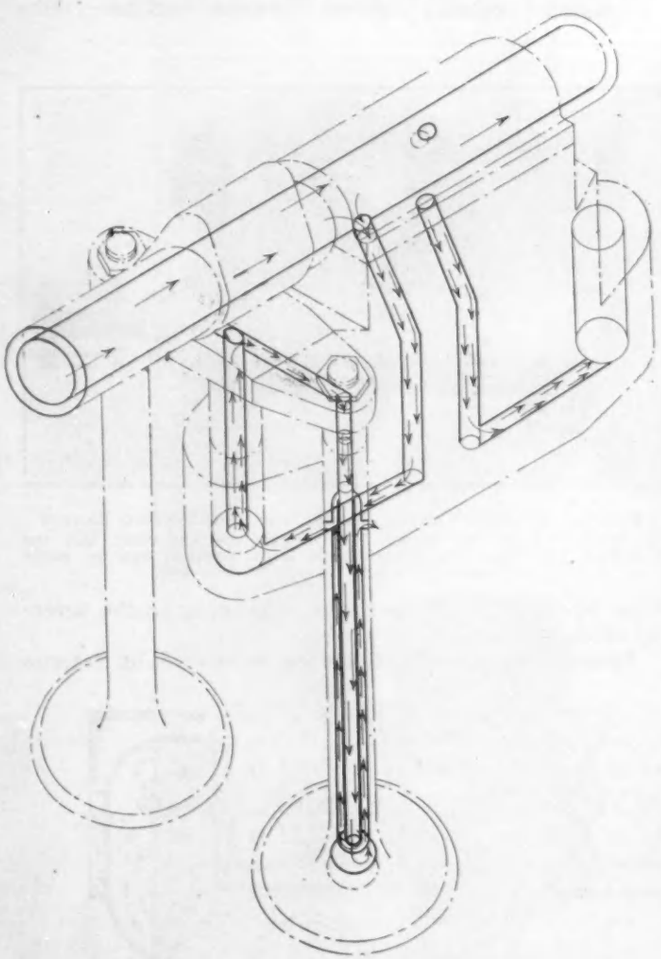


Fig. 9—Method of Cooling the Exhaust-Valves by Circulation of Oil

The Camshaft Is Hollow and Is Supplied with Oil under Pressure through a Continuous-Metering Groove in the Rear Bearing

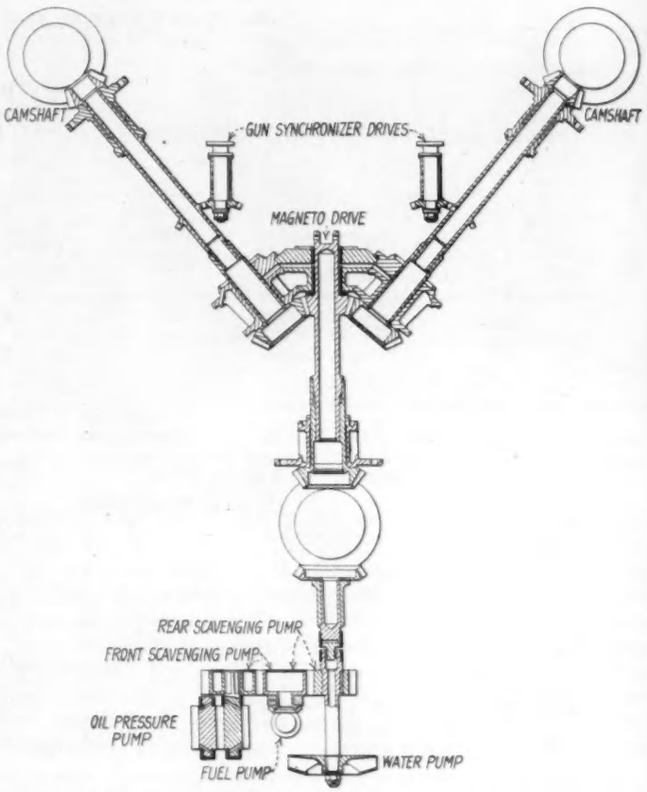


Fig. 10—Diagram of Timing-Gear and Accessory-Drive Layout

Note Simplicity, Integral Construction of Shaft and Gear, and Pressure-Lubricated Chilled-Aluminum Plain Bearings

A summary of the more interesting tests is shown in Table 2. It should be explained that the last column indicates a *PV* value that could be maintained for a period of not less than 1 hr. without seizure and does not necessarily mean that the bearing would not withstand higher loads and higher speeds for a shorter interval, or with more clearance or still higher oil-pressure. A complete investigation, in which all the different variables were altered a fraction at a time, would necessitate years of work, but the tests described accomplished what was desired in the time available.

Comparison of *PV* Values

In the same table is presented a comparison of the *PV* values employed in the Liberty and in the new Packard engine. In spite of the fact that in some cases the values of the new engine exceed those of the Liberty by more than 50 per cent, tests to date have indicated that the new bearings will have at least double the life of the corresponding Liberty bearings. This could never have been accomplished had we been content to follow so-called good engineering practice that stipulated some arbitrary maximum *PV* value with no relation to what limited the life of aircraft-engine bearings in actual service.

The permissible rubbing factors in the new crankshafts having been determined and these rubbing factors

being recognized as independent of the diameter of the journals, the problem of designing the shaft itself remained. It was desired to keep the weight of the shaft down to the minimum, Liberty engine experience having shown that additional rigidity in the shaft is highly desirable, not so much from the standpoint of avoiding crankshaft failure, for such was extremely rare with the Liberty, as of avoiding persistent troubles with the timing-gear train that are induced by torsional vibrations of the crankshaft.

The new shafts, therefore, were designed so that the primary critical speed would occur far beyond the operating range of the engine. The factors entering into the determination of the critical speed are, mainly, the rigidity of the crankshaft and the mass inertia of the crankshaft and of the parts in any way connected with the crankshaft, such as the connecting-rods, the pistons and the propeller.

W. R. Griswold is responsible for this phase of the design. Under the action of the harmonic forces of the rotating and the reciprocating parts, an originally straight element of the crankshaft is deflected at the critical speed. The portion of the shaft to the right of the node is displaced in a direction opposite to the section of the shaft to the left of the node, the vertical distance measured from the axis of the crankshaft representing the amplitude at the various sections. The critical speed of vibration varies as the square root of the inverse ratio of amplitudes; the critical speed of the Packard Model 1500 crankshaft is 64 per cent higher than the critical speed of the Liberty.

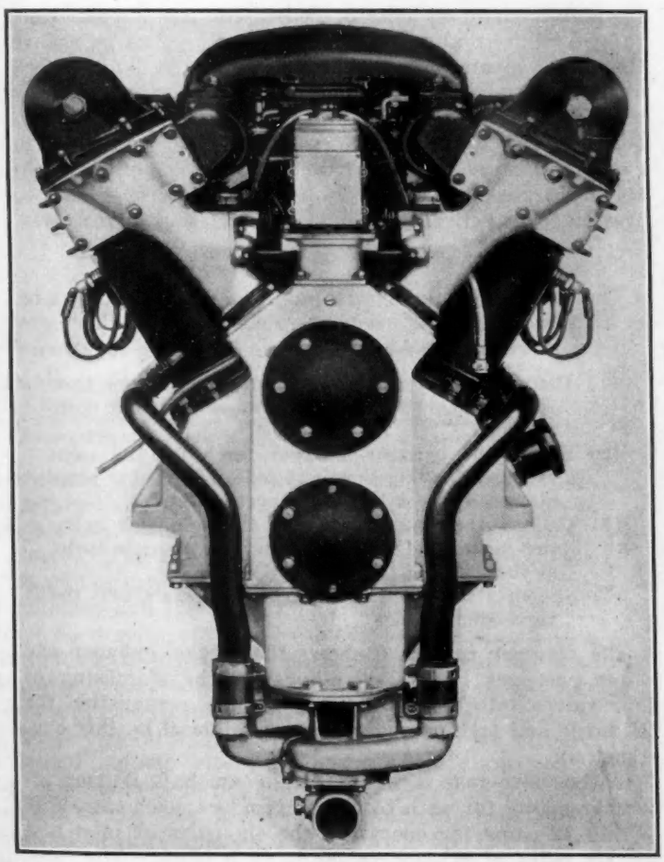


FIG. 11—REAR VIEW OF MODEL 2500 ENGINE
Maintenance Is Facilitated by the Simplicity of the Accessory-Drive Layout and the Absence of Engine Accessories Projecting to the Rear of the Engine

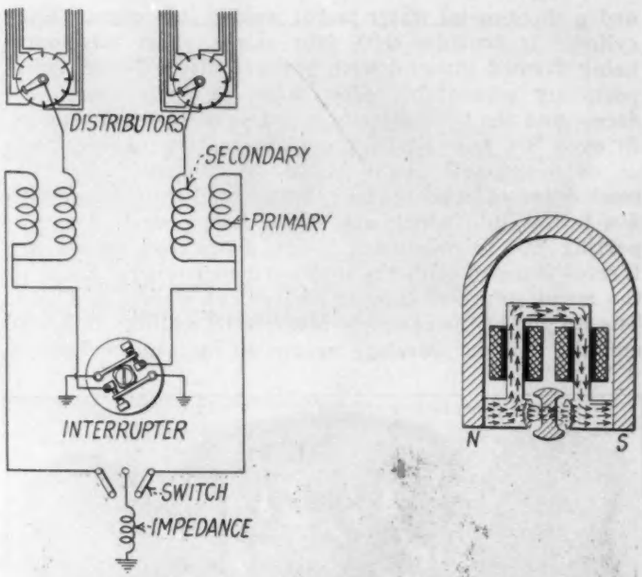


FIG. 12—DIAGRAM OF MAGNETO CIRCUITS AND WIRING
The Magneto Comprises One Magnetic and Two Independent Electrical Circuits

CRANKSHAFTS

The Packard crankshaft is about twice as stiff as the Liberty shaft, although the weight is approximately 30 per cent less. This was sought and accomplished by the use of journals having comparatively large outside diameters but bored out through their centers, so that relatively great stiffness accompanied by light weight is provided. The practical result in the finished engine has been a marked improvement in smoothness of operation and in freedom from wear in the timing-gear train. In the Liberty and other aircraft engines with fairly limber crankshafts, it has been noted that the non-driving faces of the gear teeth showed fully as much wear as did the driving faces. That this characteristic is entirely absent in the new Packard engines offers practical proof of the attainment of a satisfactory degree of rigidity in the crankshaft design.

As no precedent, that it was necessary to follow, existed in cylinder construction, a very careful analysis was made of all the existing types. Generally speaking, three types of construction that are worthy of serious consideration are in use and these are shown in Fig. 4. At the extreme left is shown the well-known Liberty design, used also in post-war types of Packard aircraft engines. The left central view shows the aluminum-block construction with dry sleeve, and the right central, the aluminum-block construction with wet sleeve. An analysis of the requirements indicated that two major considerations would dictate the choice of cylinder design for the new engine. One was, that adjacent cylinders should be spaced as closely together as possible, so that the bulk and weight of the engine as a whole would be diminished; and the other was, that the cylinder-assembly should be as light as possible.

CYLINDER CONSTRUCTION

The cylinder construction evolved as a result of this study is shown at the extreme right of Fig. 4. Each block is composed of six individual cylinders attached to a single aluminum casting that is termed the valve-housing. The individual cylinder is composed of a drawn-steel sleeve welded to a forged combustion-chamber head machined completely, and having a head-plate

and a sheet-metal water-jacket welded into place. Each cylinder is provided with four valves, short valve-ports being formed integral with the cylinder. These valve-ports are accurately hollow-milled on their outer surfaces; and the head-plate is bored so as to form a press-fit over the valve-ports, the plate seating on shoulders so as to provide about $\frac{3}{8}$ in. water-space above the combustion-chamber. The cylinder-head is provided with five bosses into which are screwed long studs for supporting the valve-housing. The spark-plug bosses are formed integral with the combustion-chamber. Steps in the manufacture of these cylinders are shown in Fig. 5. The weight of the complete Model 1500 cylinder is 9.5 lb. and the cylinder develops nearly 50 hp.; the weight of

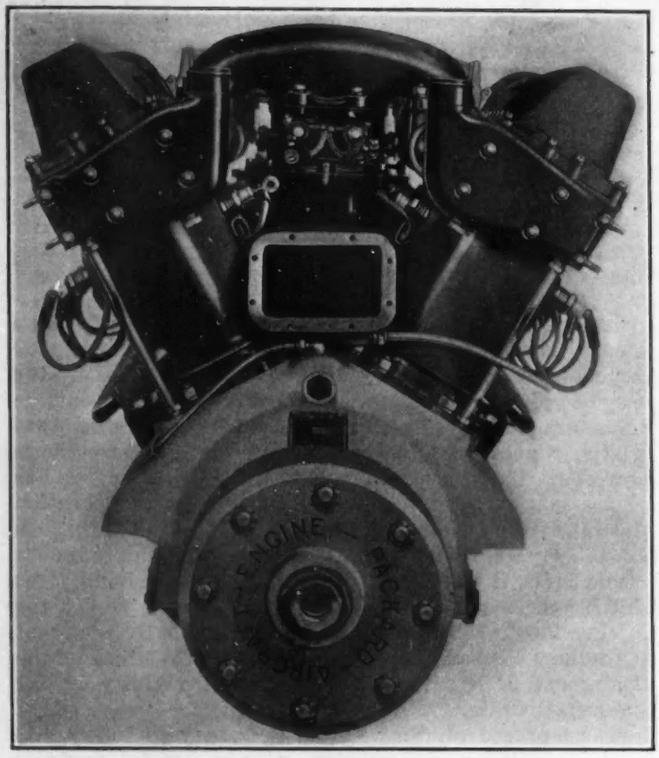


FIG. 13—FRONT VIEW OF MODEL 1500 DIRECT-DRIVE ENGINE
The Propeller-Hub Is of the Taper-Fit Type and Carries a Forged-Aluminum Loose Flange, Which Is Not Keyed or Otherwise Located on the Propeller-Hub

the complete Model 2500 cylinder is 15.2 lb. and the cylinder develops nearly 70 hp.

The advantages of the new cylinder-construction may best be studied by comparing it with the other designs shown. The first point in its favor is that it provides water circulation in close contact with all the heated surfaces, which is not the case with the closed-type sleeves shown in the two central views in Fig. 4. Another point in common with the first two designs is, that the steel cylinder-barrel is used as a wearing-surface and carries the explosion loads down to the crankcase, which is not done by the dry-sleeve cylinder, in which the aluminum water-jacket assists in withstanding the heavy loads.

LOCATION OF HOLD-DOWN FLANGE

Another advantage that also applies to the Liberty cylinder is that the hold-down flange is located some distance from the end of the cylinder barrel and allows a very compact construction, as the ends of the barrels of the cylinders of the two banks can practically be allowed to touch inside the crankcase; this method of construction also serves to add depth to the crankcase with a considerable gain in rigidity. Another incidental advantage accruing from this construction is that the engine can be run successfully in an inverted position. Inverted engines, when used in airplanes, have three major points in their favor: (*a*) greatly improved vision for the pilot; (*b*) a higher line of thrust; and (*c*) greater propeller-tip clearance. Other advantages of individual-cylinder construction are ease of manufacture, ability to install the largest possible valves while maintaining adequate water-circulation around all the valve-seats and, finally, a cylinder-spacing arrangement closer, it is believed, than is possible with any other construction.

The aluminum valve-housing is bolted to the six cylinders to form a cylinder-block; and this block remains assembled in this fashion throughout all the usual assembling and disassembling operations, although, if necessary, an individual cylinder can be replaced at any time with the minimum of delay.

Fig. 6 shows the right side of the Model 1500 engine. It will be noted that the cylinders are placed very close together and that the valve-housing design results in a compact and clean construction. Fig. 7 shows the left side of the Model 2500 engine. The similarity in design of the 500 and the 800-hp. engines is apparent, all the features described in this paper being common to both engines and, in a few instances, the actual parts being interchangeable.

Water is led into the individual cylinders from a manifold connected to short pipes welded to the jacket at the lower end. The water delivery from the cylinder is through a series of holes drilled in the top plate and arranged radially about the exhaust-ports so as to ensure that local steam-pockets will not be formed above the exhaust-valve seats. A single copper-asbestos gasket is used between the individual cylinders and the valve-housing, this gasket, of course, not being subjected to gas pressure as is the conventional automobile detachable-head gasket, but merely serving as a water-seal to prevent leaks between the inlet and the exhaust passages.

VALVE-HOUSING

The valve-housing is an aluminum casting machined on all surfaces. It is used interchangeably on the right and the left banks and performs the following functions:

(1) Distributes the mixture to the six cylinders from the two carbureter cross-header manifold connections
(2) Forms the exhaust-passages, each two adjacent cylinders having their two pairs of exhaust ports siamesed into a single exhaust outlet
(3) Collects the water circulated through each cylinder-jacket and delivers it through a single outlet at the front of the engine
(4) Supports the camshaft-bearing pedestals and the valve-stem guides

The diagram in Fig. 8 shows the intake, exhaust and water passages in the valve-housing, the siamesing of four valves into one port being largely responsible for the large and free passages that are allowed by this construction.

In the valve-gear layout, a single camshaft is used interchangeably for each block of cylinders, each camshaft having 12 cams for operating the six pairs of inlet and the six pairs of exhaust-valves in each block. The camshaft is mounted in seven heat-treated cast-aluminum split bearings that are held down to the valve-housing by long cylinder hold-down studs. Hollow dowels locate

the bearings accurately in line. Each bearing-pedestal carries integral guides for the adjacent cam-followers, the alignment of which transversely to the camshaft is maintained by engagement with the flat faces above the guides. Means for cooling the exhaust-valves by the circulation of oil are provided by suitably drilled passages in the camshaft-bearings adjacent to the exhaust-cams, this feature of the construction being shown diagrammatically in Fig. 9. The camshaft is hollow and is supplied with oil under pressure through a continuous-metering groove in the rear bearing.

Cooling of Exhaust-Valve

In the camshaft journal next to each exhaust-cam is drilled a hole opposite to the nose of the corresponding

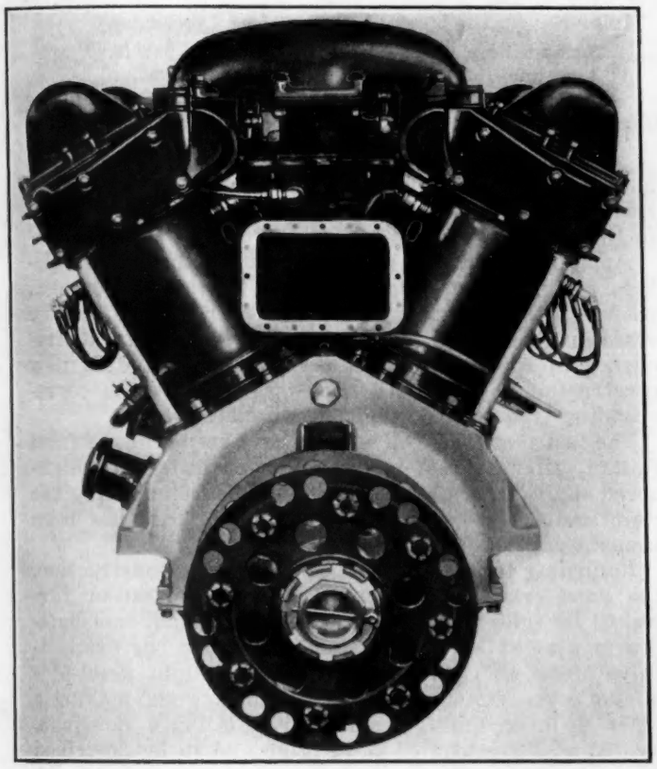


Fig. 14—Front View of Model 2500 Direct-Drive Engine
A Splined Hub with Split Centering-Cones Is Used To Prevent the Galling and Freezing of the Propeller-Hub that Sometimes Occurs in Large Sizes of Engines Having the Taper Construction

exhaust-cam. This hole registers with a vertical passage in the camshaft-bearing pedestal when the cam is at its highest point and the exhaust-valves consequently are closed. The oil flows through this passage to the bottom of the cam-follower guide, which forms a closed-end cylinder, and the space underneath the cam-follower is thus filled with oil. The camshaft in revolving cuts off communication with this passage and, when the cam-follower is depressed by the cam, the oil can escape only by being forced through the hollow cam-follower stem and the horizontally drilled passages leading out through the drilled tappets into the exhaust-valve stems. The latter are drilled throughout their entire length, the lower end of the hole in the valve-head being closed by a screwed-in plug. A small steel tube is welded to this plug and is centered in a counterbore at the upper end of the valve-stem. The oil is forced down through the tube and out at the bottom through horizontal holes, thus cooling the head of the valve. The oil is then discharged

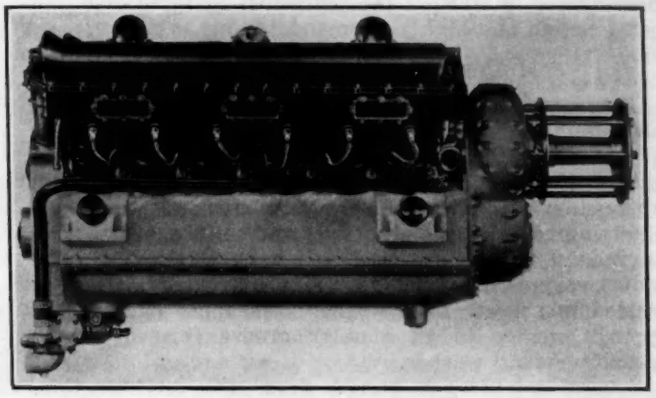


Fig. 15—Right Side of Model 2500 Geared Engine
The Gears Are of the Spur-Gear Single-Reduction Type and Are Entirely Self-Contained

through the annular space between the tube and the inner wall of the valve and out into the valve-housing through horizontal holes drilled through the upper end of the valve-stem just below the counterbore. With this system, a positive means of cooling is provided by which a fixed quantity of oil is pumped through each exhaust-valve whenever it is opened. As a result, the exhaust-valves operate at a very low temperature and the valve-seat is preserved in excellent operating condition for long periods.

The rate of oil-flow, the size of the oil passages, and other pertinent data were all obtained by a bench set-up of a single valve heated by a Bunsen burner, this study resulting in a final design from which all experimental features had been removed long before the engine had been tested in its entirety. Incidentally, this method of

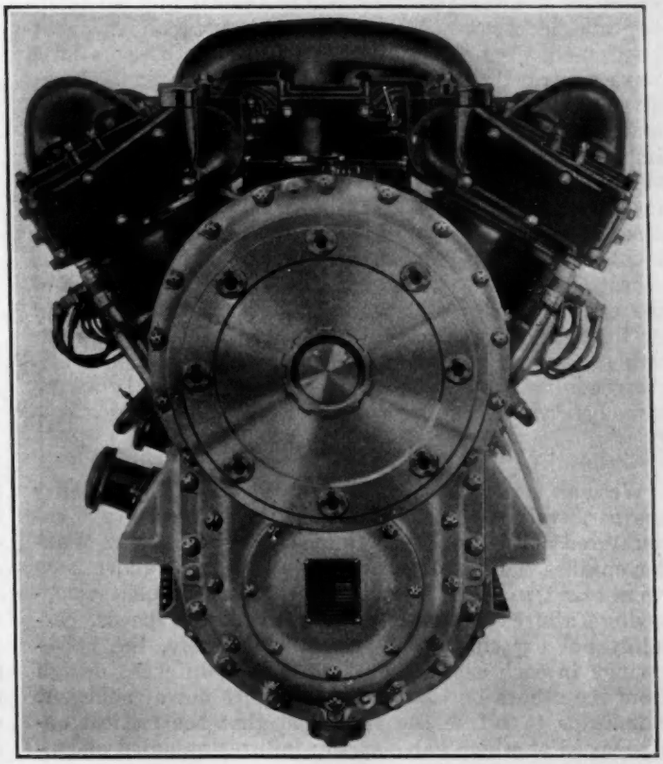


Fig. 16—Front View of Model 2500 Geared Engine
A Two-to-One Reduction to the Propeller-Shaft Has Been Found Particularly Desirable for Load-Carrying Airplanes of Moderate Speed

proving out in advance the individual features of a new construction is a highly commendable one to follow.

Multiple-Cluster Valve-Springs

Returning to a description of the valve-gear in these new engines, the valve-springs are worthy of special note. These are of the multiple-cluster type and consist of a group of small-diameter piano-wire springs arranged in a planetary fashion around the valve-stem. In the Model 1500 engine, 7 of these springs and, in the Model 2500 engine, 10 springs are used with each valve. The individual springs are located over tubular guides that are welded to a lower fixed washer; the upper ends of the springs engage in an annular groove formed in the movable spring washer.

Several advantages accrue from this construction, which may justifiably be termed indestructible. The most important point, perhaps, is the least obvious, namely, that which relates to the natural period of vibration of the small springs. This phase of the problem is discussed at length below. Other advantages result from the increased factor of safety in numbers, so to speak, since any valve will continue to function even though several of the springs may be broken. Furthermore, the reciprocating weight, represented by the upper washer and one-half the weight of the springs, is reduced, as compared with the conventional construction, and, finally, the physical properties of the small-gage piano-wire are generally superior to those of springs heat-treated after forming. Considerable effort was devoted to arriving at this valve-spring construction, which, it is believed, is of sufficient general engineering interest that the history of its development should be traced.

Valve-spring failures have always been prevalent to a certain extent in aircraft engines; and these failures at times lead to disastrous results with overhead-valve engines for the valve may drop into the combustion-chamber and, consequently, wreck the piston and the combustion-chamber head. For some time, these failures were regarded as not being preventable, the cause being attributed to fatigue and to minute imperfections in the material. The first serious consideration of this very important subject appears on record in the British Advisory Committee for Aeronautics' Report No. 241, issued in March, 1916, in which the whole matter is very ably discussed. It is clearly proved that the basic seat of the trouble lies in a resonance effect between the natural vibrations of the spring and the forced oscillations of the engine. These latter oscillations are brought about by the firing impulses. It is of interest to note that our own experience with various types of multi-cylinder aircraft engine has led us by an independent route to the same conclusions as those of the British.

Causes of Valve-Spring Breakage

We had noted that, in very high-speed six-cylinder engines, valve-spring breakages were frequently encountered at speeds in excess of 4000 r.p.m.; in 12-cylinder engines the limiting speed appeared to be above 2000 r.p.m.; and in some 18-cylinder engines frequent valve-spring failures occurred at very moderate speeds, certainly not exceeding 1600 r.p.m. Naturally, the valve-springs in each case were of somewhat different design from the others but the variations were not of sufficient magnitude to refute the statement that the critical engine-speed at which valve-spring-failures assumed alarming proportions was inversely proportional to the number of cylinders or of the firing impulses. It was apparent, then, that, if valve-spring breakages were to be avoided in 12-cylinder engines running at speeds greater than 2000 r.p.m., the characteristics of the spring with respect to its natural period of vibration must be altered.

TABLE 3—CHARACTERISTICS OF SPRINGS

	Single Valve	Multiple Type
Diameter of wire, in.	0.120	0.055
Mean diameter of coil, in.	1.453	0.336
Number of effective coils	11	28
Rate of build-up, lb. per ft.	104	152

Examining a simplified expression for the periodic vibrations of valve-springs, we find that

$$t = 2\sqrt{(WL/Sg)} \qquad (1)$$

where

g = equals acceleration due to gravity
L = length, in inches, of the wire in the active coils of the spring
S = stiffness, or rate of build-up, in lb. per ft.
t = time, in seconds, of one complete vibration
W = weight, in lb. per in. of length, of the wire in the spring

In Table 3 are given the corresponding dimensions and characteristics of a conventional or single valve-spring, as compared with those of the multiple type used in the new construction.

Applying formula (1) it will be found that the single-type spring has a frequency of 72 vibrations per sec., whereas, in the multiple-type, the frequency is 250 vibrations per sec. In other words, the natural frequency of the small-diameter springs used in the new construction is about 3½ times as high as the corresponding frequency of the conventional spring.

The fact that the small springs have been immune from failure, after a great many prolonged tests with high-speed engines, goes a long way toward substantiating the claim that valve-spring breakage in the past has been brought about by synchronized vibrations.

Returning to a description of the engine construction, the valve-gear operates with copious lubrication furnished by full-pressure feed to the individual camshaft-bearings aided by the oil discharged from the exhaust-valve stems at each opening. A very light sheet-aluminum cover, fastened to the valve-housing and making a taper fit over the ignition distributor-drive housings, located at the center of the engine and to be described later, prevents external leakage of oil. Oil from the valve-housing is returned to the crankcase through liberal drains, placed at both ends of the engine and provided with oil traps to prevent crankcase vapors from accumulating in the valve-gear compartment.

Timing-Gear and Accessory-Drive Layout

The timing-gear and accessory-drive layout is shown in Fig. 10 and is worthy of note, (*a*) for its simplicity, the minimum number of gears being employed; (*b*) for the integral construction of the shaft and the gear, wherever permissible; and (*c*) for the use of pressure-lubricated chilled-aluminum plain bearings throughout, these three features combining to save considerable weight while preserving the utmost dependability.

The simplicity of the drives was accomplished by grouping the accessories in a manner that produced an important additional saving of weight. All fuel, oil and water pumps were combined into a single unit that is used interchangeably on both the Model 1500 and the Model 2500 engines. This unit is driven through an Oldham coupling from a short shaft journaled in the rear bearing-cap. This shaft carries an integral bevel-

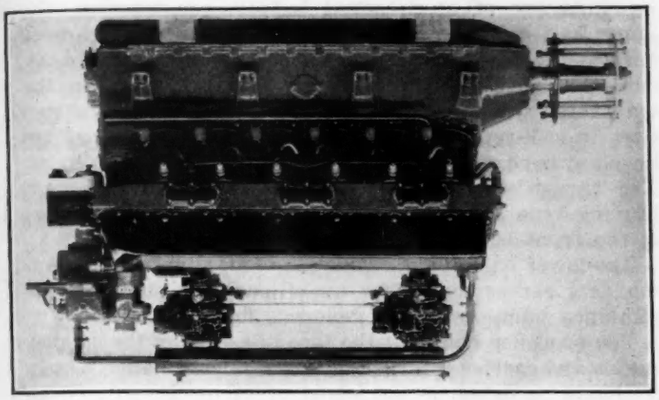


FIG. 17—RIGHT SIDE OF MODEL 1500 INVERTED ENGINE
The Inverted Type Has Four Major Advantages: (*a*) Improved Visibility, (*b*) High Center of Thrust, (*c*) Accessibility for Maintenance and (*d*) Gravity Fuel-Feed

gear at its upper end that meshes with a bevel-gear mounted on an extension of the crankshaft.

The rear view of the Model 2500 engine, shown in Fig. 11, illustrates the simplicity of the accessory-drive layout as compared with those of previous types of aircraft engine; and the absence of engine accessories that project to the rear of the engine will be appreciated by those who have had maintenance experience with aircraft engines installed in a crowded position against the fire-wall or the front bulkhead of an airplane.

The pump unit contains three spur-gears that are housed-in to form the two oil-scavenging pumps; and these gears, in turn, each drive another unit, the first driving the water-pump, the second, the fuel-pump, and the third, the oil-pressure pump. The whole pump-unit is very compact and weighs only 16 lb., including the oil-strainer and the oil-pressure-relief valve.

MAGNETO

The camshaft central drive-shaft is also formed with its gears integral and is continued through the top of the crankcase to drive the special magneto by a laminated spring-coupling. This magneto is based on a principle invented by Packard engineers and developed by the Splitdorf Company, and may be briefly described as a single mechanical instrument with all the electrical parts duplicated and independent throughout. That is to say, there are only one set of magnets, one set of pole-pieces, one rotor, one driving-shaft, one coupling, one cam and one set of rotor bearings.

On the other hand, there are two primary and two secondary coils, two condensers, two interrupter-arms, and two sets of contacts, as well as double external binding-posts leading to the two separate distributors, either one of which will fire all 12 cylinders and each having its separate drive from one of the camshafts. The magneto employs but one magnetic circuit; and the two electrical circuits are independent of one another throughout. The inductive effect between the two primary windings is eliminated through the use of an impedance coil in the switch-to-ground circuit.

In Fig. 12 is shown a simplified diagram of the magnetic and electric circuits employed in this magneto. It will be noted that this instrument differs radically from the two-spark magneto used formerly to a considerable extent. In the older type, it was customary to utilize both ends of the secondary winding, the high-tension circuit being to one spark-plug to ground and from ground back through the other spark-plug. In this type, practically all electrical failures result in both sets of spark-plugs being simultaneously affected, whereas in the new magneto the two electrical systems are completely isolated from one another and, should one system fail, the operation of the other will not be appreciably affected.

Timing of both the magneto and the distributors has been facilitated in these new engines by specially developed mountings, the magneto being furnished with a slotted flange at the driving end and the accurate timing being accomplished by swinging the magneto bodily on this mounting, two 5/16-in. nuts serving to lock the magneto in its desired position. Similarly, the distributors can be rotated bodily by loosening a clamp-bolt, the final adjustment being made with the assistance of an inspection opening located over the No. 1 left cylinder terminal.

MAGNETO OR BATTERY IGNITION

A recently developed advantage of this ignition-system lies in the fact that by substituting a generator for the magneto and by providing a suitable contact-breaker on the end of the generator shaft, battery ignition can replace the magneto ignition when desirable, without any changes to the engine itself nor to the wiring between the distributors and the spark-plugs, the same distributors being used regardless of whether magneto or battery ignition is employed.

Because of this interchangeable ignition arrangement,

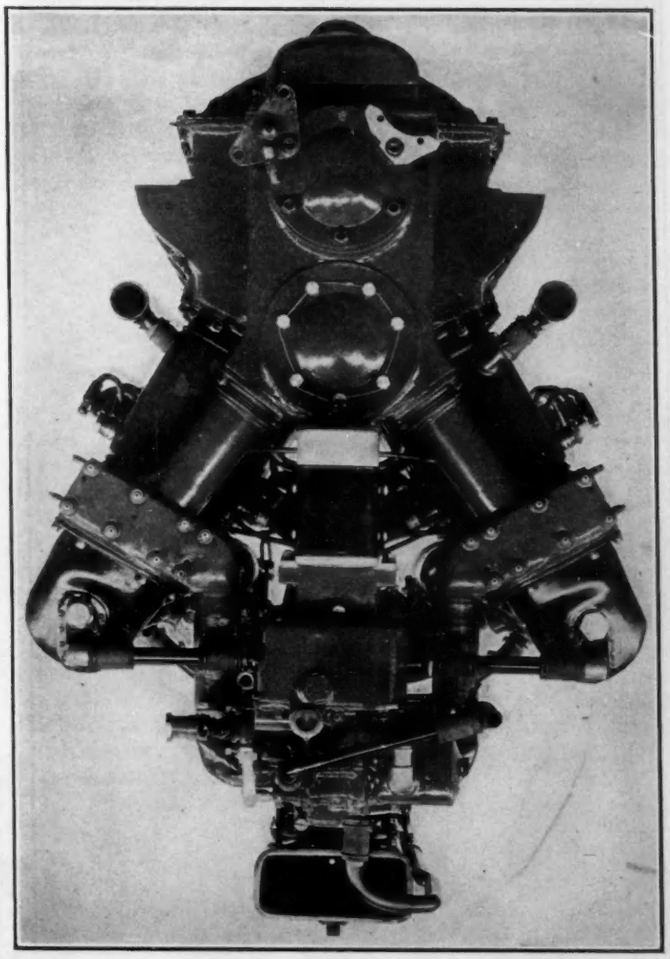


FIG. 18—REAR VIEW OF MODEL 1500 INVERTED ENGINE
Fire Risk Is Diminished Somewhat, for the Gasoline Tanks Are Confined to the Extreme Bottom of the Installation

the engines used in airplanes having little demand for electric current can be equipped with magnetos, and those in airplanes requiring a considerable amount of current, for wireless, lighting, and the like, can be supplied with battery ignition. The result is, that the weight of the engine for each class of service will be kept at the minimum and an engine can very easily be transformed from one service to another.

The pistons of both the Model 1500 and the Model 2500 engines are of special interest in that they are of the slipper type and are very short and comparatively light, although of rugged construction. The Model 1500 piston is 3 11/32 in. long and weighs 2.94 lb.; the Model 2500 piston is 3 15/16 in. long and weighs 4.47 lb., bare. The smaller piston is 5⅜ in. in diameter and has only 90 per cent of the weight of the Liberty piston although having 15 per cent more area; the larger piston is 6⅜ in. in diameter and has 63 per cent of the weight of the Shenandoah engine piston although having only 9 per cent less area than the latter. The lengths of these new pistons were established after a series of tests in which the length of the skirt was gradually diminished.

Crankcase

The crankcases of both engines are of particularly rugged design, great depth being obtained partly because of the design of the cylinder and partly because of the arrangement of the main bearings. The eight main-bearings are of steel-backed babbitt construction, the upper half being doweled to the crankcase and the lower half to the forged duralumin bearing-caps that are accurately fitted in longitudinally machined ways in the transverse webs of the crankcase. With this construction, in a V-type engine, the main-bearing bolts are relieved of bending stresses imposed by the explosion loads. The thrust-bearing is of the deep-groove radial ball-bearing type and is located between two plain bearings in the front bearing-cap.

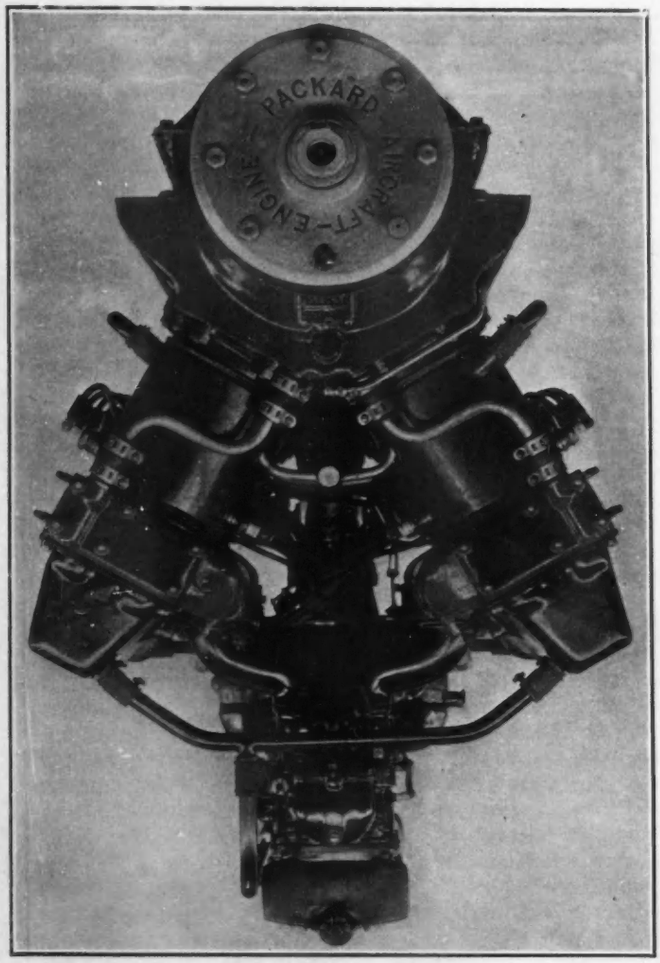


Fig. 19—Front View of Model 1500 Inverted Engine
Gravity Fuel-Feed Avoids the Use of Complicated Piping and Pumping Arrangements

The lower half of the crankcase is an aluminum stamping that serves merely as an oil-pan and supports the combined pump-unit by a generous flange.

The propeller hub is of the taper-fit type on the smaller engine and carries a forged-duralumin loose flange which, it should be noted, is not keyed or otherwise located on the propeller hub, a construction that has proved perfectly satisfactory in flight tests as well as in overload propeller-whirling tests. This feature is shown in Fig. 13. On the larger engine, a splined hub with split centering-cones is used, as is shown in Fig. 14. This construction follows precedent and is desirable in larger engines because galling and freezing of the propeller hub are experienced with the taper construction in these sizes.

The Drive

Although both the 500 and the 800-hp. engines were originally intended for direct-drive service, both have been built for use with gears, the gear-reduction forming a separate unit bolted to a special crankcase flange.

The gear reductions have been designed and built by the Allison Engineering Co., of Indianapolis. They are of the spur-gear single-reduction type and are entirely self-contained. A noteworthy feature is the employment of a shock-absorbing drive between the crankshaft and the pinion that has proved very successful in eliminating the gear trouble resulting from impact loading. Fig. 15 shows the side view and Fig. 16 the front view of the 800-hp. geared engine. These gear reductions give a two-to-one reduction to the propeller-shaft that has been found to be particularly desirable for load-carrying airplanes of moderate speed.

In addition to providing improved propeller efficiency, these geared engines lend themselves particularly well to a streamline installation; and, in this manner, improved propeller efficiency and decreased resistance combine to offer important advantages in airplane performance.

The 500-hp. engine has also been built in the inverted type and, as mentioned previously, an inverted engine has many advantages for aircraft use. It is entirely possible that the future will see the inverted engine as one of the standard types. A side view of the inverted Model 1500 engine is shown in Fig. 17, a rear view in Fig. 18, and a front view in Fig. 19.

Advantages of Inverted Engines

An inverted engine when used in airplanes, possesses four major advantages. First, in the usual type of single-engine tractor airplane, the pilot's vision straight ahead is seriously obscured by the cylinders and cowling of either a V-type or a large radial-type engine. He is practically compelled to swing the airplane from its true course to obtain a view along the normal line of flight. It is unthinkable that poor vision dead-ahead, such as this, will be tolerated when the air is as full of airplanes as we expect it to be in the future. Collisions in the air, even today, are far more numerous than would be the case if poor visibility conditions did not exist. With an

inverted engine, as shown in Fig. 17, the cowling in front of the pilot can be made to slope to meet the line of the propeller-hub spinner; in this way, favorable vision can be secured.

The second major advantage of the inverted engine lies in the high center of thrust that ensures better flying qualities, in that it offsets the tendency of the airplane to climb when full power is on. The additional propeller-tip clearance is also desirable from a consideration of taxying over rough ground and, in some cases, removes the limitation on the diameter of the propeller that would otherwise exist.

A third point in favor of the inverted engine is its accessibility to a mechanic working on the ground. If the engine mounting is properly designed and the cowling suitably arranged, the engine can be readily worked on from the ground without the necessity for stepladders and other equipment. Furthermore, the crankcase covers can be removed and the bearings examined, should this be desirable.

The fourth point in favor of the inverted engine has regard to the location of the carbureters that, in many installations, will allow gravity fuel-feed and will avoid the use of complicated piping and pumping arrangements. The fire risk is also diminished to a certain extent with this arrangement, for gasoline leaks are confined to the extreme bottom of the installation, and covering the whole exterior of the engine with gasoline, as is normally the case, is not possible.

Taking everything into consideration, we must bear in mind that commercial aviation practice at present is in a very fluid state and sentiment with reference to the ideal powerplant may be expected to crystallize along any one of several different lines; among these possibilities the inverted V-type engine stands out with some attractive features.

Conclusions

This discussion would be far from complete were we not to attempt to draw some conclusions from the accomplishments described. At the outset, stress should be laid on the statement that the advance made by reducing the weight of aircraft engines to approximately 1.4 lb. per hp. represents but one of the infinitely small steps that must be taken before the commercial possibilities of aviation can be adequately realized.

It is encouraging, however, to note that, with each advance in engine design, important improvements in airplane design immediately follow; and these alternate steps typify the sound progress that is being made in aviation. Incidentally, the interrelated advances in the design of the airplane and of the engine result in continual improvements in airplane performance that, from a military standpoint, result in maneuvering qualities of a highly sensational nature.

As an example, the daring and highly skilled pilots composing the First Pursuit Group at Selfridge Field are engaged daily in maneuvers that would have been impossible a few years ago.

With airplanes that weigh complete little more than an engine of corresponding horsepower would have weighed several years ago, most astonishing performances are possible. For instance, such maneuvers included what amounts to a climbing tail-spin, that is, a vertical barrel-roll, and several barrel-rolls at the top of a loop, with practically vertical zooms for hundreds of feet. Needless to say, maneuvers such as these and the terrific acceleration that results from catapulting airplanes from battleships produce difficult problems in engine operation, particularly with reference to carburetion; in this way, progress in engine and airplane evolution adds new problems to be solved.

The Future

Turning now to the future, it may be of interest to speculate toward what direction progress in aircraft engines will lead. Contemporary problems in this field are well defined and consist largely of detailed improvements calculated to yield lighter and more reliable engines that will be more economical with respect both to first cost and to operation and maintenance. Although experimental effort in engine development is being continually directed along unconventional lines, such as the barrel and cam types and engines employing the Diesel or semi-Diesel cycle, reasons exist for believing that during the next few years important advances will be made by conventional 12-cylinder water-cooled engines and by 9-cylinder fixed-radial air-cooled engines, the two types that offer the best possibilities for immediate engineering advance.

We may look forward to having available in the near future engines that will weigh about 1 lb. per hp.; and, concurrently with this development, considerable effort will undoubtedly be devoted toward reducing the specific fuel-consumption. For it should be borne in mind that an engine weighing 1 lb. per hp. will, at the present rate of fuel consumption, consume its own weight of fuel every 2 hr. So far as performance is concerned, the useful carrying-capacity of the airplane is reduced by the amount of fuel with which it is necessary to leave the ground, although, of course, the fuel load may be distributed in a more economical manner from a structural standpoint than is possible with units of passenger or freight load.

In closing, I would like to pay hearty tribute to the men in charge of our Army and Navy aircraft-engine development work who have been largely responsible for the success of the new engines described in this paper. In the first place, they have had the foresight and the courage to demand results considered impossible of attainment but a relatively short time ago and, in the second place, they have offered valuable assistance in the way of constructive criticism at various stages in the development work. With so admirable cooperation between Government and industry, we may look forward to a period of intensive aircraft development that will result primarily in an air force for National defense that will be second to none and will form the foundation for a transportation system by air on a scale that will defy our present-day imagination.

Discussion of Papers at the Transportation Meeting

THE discussion at the Transportation Meeting was constituted chiefly of written questions and oral replies. Some oral discussion was offered from the floor and several written discussions were either read at the meeting or submitted subsequently. In every case copies of the stenographic report have been submitted to the various speakers and the authors for correction and, in the case of the latter, for additional comments. These, as received, have been included.

A brief abstract of each paper precedes the discussion for the convenience of those members who wish to refresh their minds as to the points covered without it being necessary for them to refer to the complete text. Those of the members who wish to look over the illustrations that appeared in connection with the papers as originally published, or to read the complete text of these papers, will find all of them printed in the October, 1924, issue of THE JOURNAL.

DEVELOPMENTS IN MOTORBUS-BODY DESIGN

BY HUGH G. BERSIE[1]

ABSTRACT

CLASSES of service already provided by the streetcar and the passenger automobile influence the expectations of the motorbus passenger regarding the quality of transportation service afforded by the motorbus. If an operator persuades people to ride in his motorbuses, it will be because they offer safety, economy, convenience and comfort to a greater degree than that offered by competitive transportation media. Since the public has demonstrated that, under favorable conditions, it will patronize the motorbus to an extent that yields a profit to the operators, the future success of this means of transportation lies wholly within the control of the motorbus builders and those who operate it. Of the factors that determine the degree of success attained, motorbus-body design bulks very large.

Discussion of the subject is presented from the viewpoint of the passenger, as the motorbus approaches him, as he enters it and as he judges the quality of transportation it affords. He gathers favorable impressions from the attractive general appearance of a motorbus, its low steps and floors, wide entrance-doors and aisles, ample head-room and knee-room, comfortable seats and effective ventilation, lighting and heating. Therefore, these divisions of the subject are treated with a view to specifying exactly what constitutes good practice for each, illustrations and tabular data being presented.

Greater safety and comfort for the passenger are the factors that will enlarge the scope of motorbus transportation. Such attainment depends upon the economic pressure brought to bear on those who supply materials for motorbus-body construction, and upon the motorbus-body builders who avail themselves of improved materials.

THE DISCUSSION

QUESTION:—What, in your opinion, is the correct location of the emergency door?

H. G. BERSIE:—That question has been answered by the builders, because the table shows that they favor the location on the left side at the rear. It seems to me that this is probably the logical place for the door. Very many builders, who formerly located the door at the rear end, are now placing it on the left side. It depends, to some extent, on the seating arrangement. If a cross seat is to be placed across the back, it seems logical that the emergency door should be placed at the side.

CHAIRMAN A. J. SCAIFE:—The State of New Jersey Board of Public Utility Commissioners favors the door in the center at the rear. One case occurred, in which a motorbus rolled over, and the emergency door, which was on the side, was next to the ground. Inasmuch as the body was more than 7 ft. in width, it was impossible for the passengers to get out through the front door on the right-hand side, because the door was above their heads. It was necessary to chop a hole in the roof. If a body should roll onto its right side and the left-hand door was at the top, a corresponding condition would prevail.

A MEMBER:—On passenger coaches, two permanent doors are always open. When a motorbus turns over, passengers are always pulled out of the windows. They never go out the door. Twenty-five persons will not line up and go out the emergency door, no matter where the door is. So long as the law insists on emergency doors, it seems to me that the industry should get together and put the emergency door on the left side at the driver's left. There the door will be of some use. The driver can use it. I do not mean after a wreck. I mean when he must get out to attend to the engine and a crowd is around the exit. The emergency door at the left side at the rear is of no use, so far as we have found. I have written to insurance companies, and they have reported that in none of the motorbuses that overturned was the emergency door opened. That was before the New Jersey accident. The accidents were in California, and the passengers crawled through the windows.

R. E. FIELDER:—The arguments about the use of the emergency door and the use of the windows seem to lead to the suggestion that certain dimensions should be created for the size of windows. I know of hundreds of motorbuses in which one cannot get through the windows without breaking the frames. The point is, to make the window columns far enough apart so that a fair-sized person can get through them.

CHAIRMAN SCAIFE:—A committee appointed by the Council of the Society is working on this question at the present time. The Society is not yet ready to have a Standards Committee Division on Motorbuses. The

[1] M.S.A.E.—Engineer, Haskelite Mfg. Corporation, Chicago.

committee that has been appointed is a sort of steering committee to work with the street-railway interests in trying to standardize door widths, window heights and the like. I was very much surprised to find that, in the street-car industry, as old as it is, these dimensions are not standardized.

QUESTION:—Do purchasers of motorbuses prefer a 20-in. aisle and 32-in. seats to a 16-in. aisle and 34-in. seats?

MR. BERSIE:—These data were secured not from purchasers but from body-builders. One would expect them to reflect, in a way, the desires of the operators. Referring to the table, we find that their opinions are about evenly divided. The greater number prefer the 34 or the 35-in. seat. A few prefer 32 in. The tendency seems to be toward a wide seat and a narrow aisle.

It has been found in the street-car field that if the seats are made too wide and the aisles too narrow, the time required to load and unload the motorbus will be increased materially. In other words, loading time will be sacrificed for the greater comfort of the passengers. It does no good to cut down the width of the seat, say to 30 in., because the passenger nearer the aisle will project beyond the seat and block the aisle. We might as well put the seat under him, because he will stick out anyway.

QUESTION:—What is the most comfortable manner of constructing seats over wheel-housings?

MR. BERSIE:—It is very difficult to get a comfortable seat over the wheel-housing.

QUESTION:—Do you recommend cross or longitudinal seats?

MR. BERSIE:—The tendency, from the data obtained, is toward cross seats. The Yellow Coach Mfg. Co. uses them in both double and single-deck motorbuses, and many other builders seem to follow that practice.

QUESTION:—Please give a more detailed description of Plymetl roofing and flooring, the methods of fastening it to posts and the like.

MR. BERSIE:—Plymetl material is employed not for the roof but for the floor and the side panels.

QUESTION:—What about drumming?

MR. BERSIE:—We have had no trouble with drumming in motorbus bodies. In the past, we did have some difficulty especially in taxicabs, but the drumming was overcome by using heavy material. They went to the extreme in trying to reduce the weight. The fastening of the material to the posts was shown in Fig. 11 of my paper.[2] That is not the only method, but the figure shows the manner of fastening the panel in the case of steel framework. With wood, it is customary to use ordinary wood-screws. The head of the screw is covered with a light molding.

QUESTION:—What has been done to bring the life of the body-sills to the maximum life of the chassis, that is, with respect to deterioration by water?

MR. BERSIE:—Considerable work, I understand, has been done by the Yellow Coach Mfg. Co. and I think also by the Fifth Avenue Coach Co. along this line. I can say, in a general way, that they have tried the use of a molding to drain the water from the sill so that no pocket will be formed to hold any water that might drain down when the windows are open. One of the plans proposed was the drilling of very small holes in the sill so that the water would drain out of the pocket. This method has the objection, however, of slightly weakening the sill, and also of the holes' becoming clogged with sediment and dirt. Personally, I think that the use of some type of filler or molding for eliminating the pocket is the better method. I have assumed that the side-sills, to which the panels are fastened, are referred to. If the question refers to the life of the main body-sills, I have no data available. The use of ash or woods of that type might help, as would also the use of a good primer to prevent the absorption of moisture.

QUESTION:—What is the best way to carry baggage?

MR. BERSIE:—The roof has been used somewhat in the Northwest for carrying baggage in intercity service. This problem would not arise in the pay-as-you-enter or street-car coach, because the baggage problem does not exist in local service.

CHARLES FROESCH:—I believe that one of the hardest problems in motorbus-body design is to blend properly or to streamline the forward part of the body with the hood, the radiator and the fenders, to obtain a pleasing appearance without impairing the roominess of the driver's compartment. In some cases, the use of a low body-skirt combined with straight sides imparts the thought of rolling boxes rather than of motorbuses.

The company with which I am connected builds a city-type motorbus of 25-passenger capacity that has a frame height of 23 1/16 in. and uses 1¼-in. floor-boards, making the floor height 24 5/16 in. above the ground. The frame is perfectly straight without a kick-up at the rear. The chassis wheelbase is 196 in. long.

Linoleum is lighter than rubber and its use as a floor covering is not so expensive.

Mr. Bersie speaks of using ⅝-in. structural plywood in a single piece for a motorbus roof. This is interesting not only because of the gain of head-room that is obtained but because of the enhanced appearance. What is the difference in weight, if any, between this novel construction and that of the standard type with ribs and covering?

Being a Parisian by birth, I might mention that the back-to-back seats used in the old Paris double-deckers were not very comfortable to ride in and whenever a turn was made the passengers on the outside seats felt it very keenly.

I believe that the day will come when wood as a body material will be a thing of the past. Duralumin has great possibilities; it is light and strong. Roofs will be built in sections to accommodate any size of body that may be required; the sections can be either rigidly bolted together or assembled to allow a certain amount of flexibility between them to take care of the bending and the twisting of the frame.

MR. BERSIE:—The saving in weight by the use of the ⅝-in. panel is in the proportion of the ⅝ to the ⅞-in. lumber that is replaced. The saving is approximately 30 per cent.

Another saving is that of white lead. I understand that at one time it was necessary on tongue and groove construction to spread as much as 100 lb. of white lead over the top in a sort of pasty mixture to fill up the cracks and make the roof waterproof, theoretically, at least. With paneling, the amount of white lead needed is greatly reduced, so that in addition to a saving in the thickness of the paneling, we have a saving in weight because of the smaller amount of lead that is necessary.

A MEMBER:—Nobody has expressed ideas about weight. When we buy bodies, we have definite ideas of head-room, width of seats, aisles, and steps. We also have definite ideas about weight, but we do not know how to tell the body-builder to lessen it.

[2] See THE JOURNAL, October, 1924, p. 351.

Body-builders are of two classes. One class consists of men who have been building street-car bodies; the other comprises the body-builders who come from the ranks of the wagon and truck-body builders. Any one who has had much experience in building bodies feels the lack of engineering practice insofar as it is applied to body-building in the automobile industry. We ask for certain weights. They are promised, but the result is either a body that is very heavy and gives good service, or a light body that will not stand up in service for any length of time.

I think that what we need, in our company, at least, is an engineer that knows the requirements of passengers and has been working on weight reduction. The bodies that we ourselves build are too heavy. We do not know how to reduce the weight without getting a body that will not stand up. Within the last year we began to build a light body. Whatever we do to make the body stronger makes it heavier. What we are worrying about is how to get a body that is light and will stand up.

CHAIRMAN SCAIFE:—It will doubtless be possible to get bodies that will give service and be lighter than they are today. Whether they will be of wood or of metal is a question. It seems a crime that a vehicle carrying 3000 or 4000 lb. of load should weigh from 9000 to 11,000 lb.

C. M. BILLINGS:—How much lighter could motorbus bodies be made if they were not subject to the strains produced by a flexible weaving frame?

A MEMBER:—A rigid frame cannot be built. Weaving is a condition that we cannot overcome. Bodies are too heavy. I do not know of anything that has been done along the lines of lightening the body. We can build light bodies, but they are not good.

MR. BILLINGS:—It is my experience that, with correct spring-suspension, a frame can be built sufficiently rigid to enable the use of lighter bodies.

A MEMBER:—The chief engineer of the Berlin Motorbus Co. has said that he would not buy American bodies because they are too heavy. He builds double-deck motorbuses having a total body-weight less than that of any single-deck body in the United States. He accomplishes this saving through the use of thin wood. With that construction, he gets greater strength and a little more than one-third reduction in the weight.

MR. BERSIE:—I feel that the primary "reason for being" of the structural plywood products in the bus field lies in the fact that they make possible light weights without sacrifice of durability. For example, the Kuhlman body weighs approximately 300 lb. less than a body of the same capacity constructed with slat roof and aluminum panels.

MOTOR RAIL-CARS

BY JAMES W. CAIN[3]

ABSTRACT

REFERRING to the McKeen gasoline-driven car and one of the gasoline-electric type that were introduced in the early part of the present century and were the pioneers among self-propelled cars for railroad use, the author ascribes their limited success to their excessive weight and to engine and transmission troubles. Both these types, he thinks, might have been developed successfully had the gasoline engine been in its present state of efficiency and reliability.

The early attempts having been more or less unsuccessful, the construction of all types was discontinued during the war. More recently the progress in the design and construction of highway motor-trucks has caused them to be adapted to railroad service by applying flanged tires to the rear wheels, pivotal pony-trucks forward and a motorbus body for the carrying of passengers and a limited amount of baggage. These motorbus-type cars weigh approximately 600 lb. per passenger as compared with 1500 lb. in the cars originally used and can be maintained with the same ease and at less expense than can a highway motor-truck. But, although these cars were economical, they were not comfortable to ride in, and they have been superseded by slightly larger cars of light weight equipped with the same automotive-type engine but with two pairs of four-wheel pivotal trucks and swing bolsters. This is the type largely in use at present.

About 3 years ago an investigation of self-propelled cars in this Country and in Europe was made by the American Short Line Railroad Association, 500 questionnaires being sent to members of the association in this Country and in Canada; and many valuable data were acquired regarding the operation of motor cars on short lines and branch lines under all sorts of conditions. The records show that at present 135 roads are operating 164 motor cars, of which 34 are on trunk lines and 130 on short lines. The approximate mileage is 8000. The number of steam trains that have been replaced is 200. One steam road, 108 miles in length, that showed a deficit of $36,000 per year showed a profit of more than $22,000 during the first year of operation with motor cars. The total investment in serviceable rail motor-cars at present is about $2,500,000; the steam-train investment necessary to provide the same service would be from $8,000,000 to $10,000,000.

It is the author's opinion that eventually all branch lines and short lines will become motorized, the limiting factors at present being the inadequate power developed by the most approved type of motor-truck engine. A lower grade of fuel than gasoline will, no doubt, also be found eventually, which will make available a type of internal-combustion locomotive for handling freight service. Increasing the size of the engine will probably require some change in the form of the transmission, for the limit of the present clutch and transmission system has almost been reached. But this may prove to be an advantage.

Among the other economies accruing to the use of the self-propelled vehicle would be the abolition of such facilities as water-stations, coal-stations, roundhouses and the like. The cost of maintenance of the road-bed would also be reduced.

With the further development of automotive equipment the complete motorization of short-line and branch-line railroads may be expected to turn the present operating deficits into profits.

Tables are appended showing the operating statement of a motor car for 1 year and an analysis of the operating cost during this period.

[3] Manager of purchases, American Short-Line Railroad Association, Chicago.

THE DISCUSSION

F. C. HORNER[4]:—Mr. Cain represents the railroads that probably comprise the largest field for the use of motor rail-cars. I say "probably," but later on it may be that through the process of evolution the trunk-line railroads, after careful investigation, and also because the automotive industry perhaps will be able to develop a line of cars that will meet the requirements better, will find ways and means to use motor rail-cars to greater advantage than they have in the past.

C. O. GUERNSEY[5]:—Mr. Cain cites tabular data of operating costs that may be misleading because those costs perhaps cannot be obtained generally. The particular railroad responsible for the statements is operating in a territory where fuel costs are very low and, being a short-line road, it is able to pay less than the standard wage-rates. Two or three other minor items exist which tend to increase the cost slightly. An average of the motor rail-cars for the United States, so far as it was available up to about June, 1924, indicates that a fair cost for short-line operation, bearing in mind that the cost, being dependent upon conditions, always varies, is about 21 or 22 cents per car-mile for a car of the size and the weight described by Mr. Cain. On the trunk-line railroad, this cost would run between 25 and 30 cents per car-mile, again depending upon the efficiency of operation and maintenance, the number of miles run per day, the wages paid and all the other factors that enter into the cost.

Mr. Cain questions the possibility of the mechanical transmission of engine power greatly in excess of the horsepower that has already been used. It is true that, so far as existing commercial products are concerned, it is not possible to increase the amount of power very much; that is, it is not possible to go to some manufacturer of clutches, we will say, and buy a clutch of sufficient size to handle engines of from 150 to 200 hp. However, I see no reason why clutches cannot be developed especially to handle any amount of power within reason; and this applies also to other items of transmission such as the transmission itself, the propeller-shafts, the gearing, the bearings and the like. It would simply mean that these parts would have to be designed especially for the service. Undoubtedly, there is a limit of engine horsepower beyond which it would not be economical to use the mechanical transmission; but I am not sure that any one knows yet just where that limit is. However, I am sure that we have yet to reach it.

Mr. Cain mentions the possibility of hydraulic or electric transmission. Of course, such transmissions have some very decided advantages in large units, particularly with regard to ease of control. They also have an advantage from the standpoint that, for some conditions, double-end operation is very desirable. That cannot be achieved satisfactorily with the mechanical drive, in my opinion. For that type of service, I am not sure but that the electric drive or the hydraulic drive may be the solution, for use on large cars.

TRAILERS AND DEMOUNTABLE BODIES FOR MOTOR TRANSPORTATION

BY H. W. HOWARD[6]

ABSTRACT

UNDER fair conditions, the capability of good motor-trucks and good tractor-trucks, for almost continuous operation, is from 100,000 to 300,000 miles, according to the author, who interprets "almost continuous operation" to mean a service of 20 hr. per day, 6 days per week and 280 days per year, hauling loads that approximate the load capacity of the vehicle. Yet time-studies have proved that the average performance of motor trucks with load is usually 4 hr. or less per day for the 280-day yearly period, a truck usefulness of only 20 per cent of its continuous-performance ability. Characterizing this as very inefficient transportation, the author says that few motor-truck operators realize the importance of the lost-time factor, discusses the subject of time lost in service and implies that motor-truck traffic-managers should give earnest consideration to the determination of what constitutes a satisfactory day's work for the vehicle. He believes the remedy to be in the improvement of the type and size of the vehicle, the loading and unloading conditions, the type of body, the auxiliary equipment, routing and dispatching, cost records and maintenance methods.

The use of tractor-truck trailers is advocated and the respective merits of two and four-wheel trailers are set forth. The three methods of semi-trailer hauling, using one, two or three such vehicles behind a tractor truck, are explained, and the advantages of each are specified. A motor-driven vehicle specially designed to load, haul and unload sugar-cane is illustrated and described.

THE DISCUSSION

M. C. HORINE[7]:—A very complete presentation of the case for the semi-trailer has been made by Mr. Howard, but I fear he has fallen into the error of many others who have sponsored the same useful device, in overstating his case. He stated that the four-wheel trailer was the antecedent of the semi-trailer. I believe that no four-wheel trailers were regularly manufactured in this Country until long after the Knox Automobile Co., of Springfield, Mass., had been building semi-trailers in considerable quantities, for that time.

Mr. Howard says also that "Large-tonnage trucks make for a low ton-mile cost, but injure the roads. The tractor-truck, semi-trailer and other trailer combinations handle volume tonnage at a still lower ton-mile cost without injury to the roads." So bland a statement as that should not go unchallenged. The charge that heavy trucks destroy our roads has been made by politicians, in some cases, to shift the blame for the untimely destruction of highways that have been built improperly and to justify oppressive and discriminatory taxation of certain classes of citizens. It has been taken up by the railroads in an attempt to stifle what they have regarded erroneously as competition with their service. It has been furthered by associations of passenger-car owners who were seeking the maximum mileage of light-surface

[4] M.S.A.E.—Consulting engineer, General Motors Corporation, New York City.

[5] M.S.A.E.—Chief engineer, automotive car division, J. G. Brill Co., Philadelphia.

[6] Transportation engineer, General Motors Truck Co., Pontiac, Mich.

[7] M.S.A.E.—Engineer, general sales department, International Motor Co., New York City.

roads for touring use, in utter disregard of the basic economic purpose of improved highways. But, despite the great credence such belief has gained, it is still an unproved assertion. The Bureau of Public Roads in the Department of Agriculture, the Motor Transport Corps of the Army and several of the most careful engineering authorities of our universities have prosecuted research inquiry over a period of 5 years to ascertain the facts; yet, today, no one who is competent to pass upon the subject has come forward to affirm or deny the allegation.

In comparing the two-wheel with the four-wheel trailer, Mr. Howard states that the four-wheel trailer requires the truck to stand idle during the loading and the unloading of the trailer, and he goes on to say that this is not true of the semi-trailer. I am sure he will agree with me that his first statement is not true. To a very great extent, where four-wheel trailers are used, they are loaded and unloaded in the absence of the tractor exactly as in the case of the semi-trailer; to operate them otherwise would be fully as foolish as to keep a locomotive coupled to a freight train during the 48-hr. period allowed for loading and unloading the cars.

I feel that these things require more careful statement, because the semi-trailer is in more danger from its friends of not receiving the recognition it deserves than it is in danger from its enemies. No reason exists for anyone to compare motor-truck transportation with semi-trailer transportation, any more than to compare railroad transportation with truck transportation. Each has a field.

Mr. Howard has covered very ably many of the applications of the semi-trailer wherein it certainly is pre-eminent, but he has fallen into a common error in his belief that a motor truck is possessed of a mythical reserve power that enables it to haul many times its load capacity by adding weight in the form of an additional frame and wheels. That is a mechanical absurdity that can be demonstrated easily. All a tractor semi-trailer does is to provide a larger load-carrying vehicle that has two additional wheels for the same amount of tractive effort. The same thing can be done by building four-wheel trucks of larger capacity. Many classes of transportation cannot be handled successfully by tractor semi-trailer trains.

The economy of the tractor semi-trailer is also very greatly over-rated, because a 3½-ton truck with a 7-ton trailer is apt to cost as much as a 7½-ton truck to buy; and, because it is heavier and has more bearings to absorb power, it is very apt to operate at a slower speed and, for these reasons, to cost more per mile to operate. The proper sphere for the semi-trailer is distinct from that of the motor truck.

H. W. HOWARD:—In discussing the semi-trailer and the four-wheeler, it will be noted that I used the word "development." Mr. Horine is correct in making the statement that the semi-trailer no doubt antedates the four-wheel trailer, but it seems that the semi-trailer development was left rather in abeyance for a time and more attention was given to the four-wheeler. The automatic semi-trailer that we have today is of comparatively recent origin and that is why I used the word "development." I in no way implied that the four-wheeler antedated the semi-trailer.

Mr. Horine has in mind the question of impact and its effect on roads, taking into consideration the relative value of the two factors, weight and speed. Less and less attention is being paid to this item by the various State highway departments. Where the necessities of commerce require the handling of heavy traffic and tonnages between two points, it is always economy to construct a smooth hard-surface road. With this smooth surface available, the question of impact is of small importance. It is the gross weight per axle or per tire that concerns the highway engineers.

It is the best judgment of highway experts that, if a given weight is applied at a certain point, say on a concrete road, it will affect the concrete slab for approximately 7 or 8 ft. from the point. Therefore, State legislatures have sought to prevent the concentration of excessive weight by limiting the load capacity or the gross weight of vehicles. Such legislation makes it clear that the intent is to prevent such concentration of weight. This object is so accomplished when a given load is hauled on six or eight wheels instead of on four wheels, as when a semi-trailer or four-wheel trailer is used with a motor truck.

Mr. Horine misunderstood my remarks about the four-wheel trailer and the truck receiving their loads. The truck must stand while receiving its load and this lost time of the powerplant does not exist when semi-trailers are used. I agree with his statement about the two vehicles each having a place. There is no question about that, but I feel that there has been a tendency in the motor-truck industry to "pussy-foot" on the tractor-trailer proposition and to fail to state the case as clearly as it should be stated. The greatest advantage of the tractor semi-trailer lies in reducing the unloading and loading time so that the powerplant will be kept moving. Next it permits the handling of volume tonnage per unit without violating road laws. This makes for economical transportation where conditions permit of their use.

MAURICE WALTER[8]:—The application of various types of trailer equipment, as explained by Mr. Howard, is certainly very interesting. However, certain fundamental principles exist regarding the use of tractors with trailers that must be understood to avoid misapplication. The conventional type of rear-drive motor truck, when used with a semi-trailer or separate four-wheel trailers, has only sufficient traction and pulling power for operation where the grades and the road conditions are favorable. When a rear-drive motor-truck is used with either semi or four-wheel trailers, it is obvious that only about 40 per cent of the total weight is on the two drive-wheels and, on wet slippery roads, the tractive ability will be limited; in fact, when climbing a 10-per cent grade, there is danger that the drive-wheels will slip. However, by using a four-wheel-drive tractor, this limitation is effectively overcome as from 55 to 60 per cent of the total weight will be on the four drive-wheels of the tractor, in which case the tractor will have sufficient traction to negotiate even an 18-per cent grade having a slippery road surface, without such danger.

The average heavy-duty motor-truck represents a total weight of from 25,000 to 28,000 lb. In the case of large semi-trailers, this total weight is increased to 40,000 lb. and with large separate trailers, to as much as 50,000 lb. It is obvious that extra braking capacity is essential for the safe handling of the increased weights.

The ordinary type of heavy-duty motor-truck has a range of transmission reductions of approximately 5 or 6 to 1 and this is inadequate for the increased tonnage when operating with semi-trailers or separate trailers. To provide a high-gear speed of reasonable efficiency and a low gear having sufficient power to meet

[8] Jun. S.A.E.—Chief engineer, Walter Motor Truck Co., Long Island City, N. Y.

an emergency, it is necessary to build a tractor with at least a 9 or 10 to 1 range of transmission speeds. A lesser range than this will compromise the performance of the tractor-trailer train seriously.

A. F. Masury, in speaking of the advantages of six-wheel buses, made the prediction that heavy-duty buses would be built with six wheels within a few years, and pointed out the advantage of dividing the driving and the braking strains between two axles, using four wheels. The ideal unit for heavy freight-transportation is a six-wheel combination consisting of a four-wheel-drive and four-wheel-brake tractor operating with a semi-trailer, and the near future will see a very large increase in the use of equipment of this type.

PUBLIC-UTILITY EXPERIENCE WITH THE MOTORCOACH

BY V. E. KEENAN[9]

ABSTRACT

ALTHOUGH street-railway managers have had very little experience with the operation of motor-coaches until the last 5 years they have been rudely awakened by the rapid increase in the number of independent operators and are beginning to realize that a new transportation era is at hand and that new standards in mass transportation are in demand. The delay in adopting motorbuses, while considered disastrous by some, in reality has given time to determine whether the new system is merely a fad or is due to the conditions in the labor market and to the rise in the cost of materials that have prevented the railways from extending their plants and their operations. In the period from 1917 to 1923, the number of licensed automobiles increased 300 per cent while, in the same period, the number of passengers carried by the street railways increased only 10 per cent; but both indicate the need of greater transportation facilities. The highways of the Country, of which only about 20 per cent are adequate for the operation of motorbus traffic, are rapidly reaching the saturation-point; and the traffic of the future will undoubtedly increase faster than will the construction of highways. The street-railway track-mileage of the Country already exceeds its present usefulness; consequently, no form of mass transportation other than the motorbus is capable of reaching out into this field.

Within the next few weeks approximately 16 per cent of the electric-railway mileage in Providence will be abandoned because it does not pay the cost of electric operation; and motorbuses will be substituted. The comparative cost of operation of motorbuses and electric-railway cars has been found to be 24.49 and 32.90 cents respectively. By substituting motorbuses this difference in operating cost will be taken advantage of. The difference in popularity and earning power of the two systems was exemplified during a recent 3-day holiday period, the receipts of the electric-railway cars showing a decrease of $465 and the motorbuses an increase of $778 over those of the corresponding period of the previous year.

About 3 per cent of the earnings of an electric-railway car are derived from the standing load. If motorbuses are to show a greater earning ability, a larger number of seats must be provided. The field for double-deck motorbuses is limited but the capacity of single-deck motorbuses should be increased. With a view to reducing the cost of operation and maintenance the suggestion is made that attention should be given to the operation of vehicles that are larger and at the same time simpler to maintain. Charts show the net cost of electric-railway and of motorbus operation, the tendency of electric-railway earnings to fall off and those of the motorbus to rise, the cost of mechanical maintenance of four different types of motorbus, and the increase in the registration of motor vehicles annually since the earliest days of the industry.

THE DISCUSSION

A MEMBER:—Will Mr. Keenan explain how his net costs are derived?

V. E. KEENAN:—The chart on the cost of motorbus operation was derived by taking the cost of 12 months' operation on each of four different makes of equipment. In all cases the equipment involved had been in operation for almost 3 years. In reference to the so-called net cost of car operation, our feeling is that it would be useless to substitute buses for street-cars when you have all the street-car equipment, an investment in rails, power-house, overhead structure and supplementary rolling-stock, and also the men who know how to operate all of this equipment, unless a real economic advantage can be shown by the agency that would replace the existing equipment.

MARK A. SMITH[10]:—What type of vehicle did you operate?

MR. KEENAN:—All our equipment is the so-called one-man street-car type of bus, with an aisle down the center.

F. F. CHANDLER[11]:—So far as the operators are concerned, is the labor turnover an item in the four different types of motorbus used? Do some motorbuses operate so much more easily than others that the labor turnover has to be taken into account?

MR. KEENAN:—The labor turnover, while unquestionably it affects the cost of operation, is pretty well apportioned over each of the four makes. As a matter of fact, our labor turnover has been relatively low, chiefly because of the union situation.

F. C. HORNER[12]:—What about the advantages and disadvantages of four and of six cylinders for motorbus engines?

MR. KEENAN:—There is no question about the pleasant effect produced by a six-cylinder engine in the mind of the passengers. There is, however, a very great doubt that the six-cylinder engine is fundamentally as sound as the four-cylinder for motorbus service. We have been constantly asking for simpler vehicles, and, personally, I very much dislike to see any trend toward a multiplicity of parts.

MR. HORNER:—What about noise and vibration from the engine?

MR. KEENAN:—Four-cylinder engines can be built which are relatively free from vibration. Several bus-builders are actually turning out very smooth four-cylinder equipment. Much depends upon the quality of workmanship and the precision that goes along with the assembly.

[9] Superintendent, motorbus division, United Electric Railways Co., Providence, R. I.
[10] M.S.A.E.—Vice-President and general manager, Royal Motor Coach Co., Rahway, N. J.
[11] M.S.A.E.—Chief engineer, Ross Gear & Tool Co., Lafayette, Ind.
[12] M.S.A.E.—Consulting engineer, General Motors Corporation, New York City.
[13] Jun. S.A.E.—Designing engineer, Mack Trucks, Inc., New York City.

CHARLES FROESCH[13]:—What are the most troublesome parts, so far as maintenance is concerned?

MR. KEENAN:—Brakes and clutches.

MR. HORNER:—In the order stated?

MR. KEENAN:—The order varies with different types of equipment and different types of service.

D. J. LOCKE[14]:—How will the larger motorbus, which Mr. Keenan believes is coming, fit in with the demands on lines where the headways are now long and no immediate prospect of increase in patronage exists? Will not the larger motorbus, if operated economically, call for a longer headway and perhaps less real service?

MR. KEENAN:—Mr. Locke is correct in stating that the larger motorbus will ordinarily call for longer headway, if you gage the seats supplied per hour in that manner. However, nothing in our own experience, or in that of any other large operator of buses, indicates that the small-capacity motorbus has any real economic justification. The cost of operating a 25-passenger bus is only a little more as compared to a 17-passenger. Of course, the interest on the investment is materially greater but, when one considers that this larger bus blends itself into the property as a unit that can be used any place at any time, it is questionable whether or not the slight additional cost of operating a 25-passenger bus on sparsely settled routs is really so much of a disadvantage as some of the operators are inclined to feel. We have installed recently some 29-passenger units which cost no more to operate than 24-passenger buses, they are actually earning 4 per cent more per bus-mile.

MR. SMITH:—In the operation Mr. Keenan supervises, he is faced with a regulation that is not in force in many parts of the Country. In other places single-deck motorbuses carry "standees." In the territory Mr. Locke is thinking about, standing passengers are permitted and the one solution of using the smaller motorbus in doing the work of a larger bus is to have a little more distance between the seats. If the distance between the seats can be 32 in. on centers, more people can stand and can stand more comfortably. In New Jersey, most of the money is made on standees. I think the territory must be considered when it is said that the larger motorbuses are really the solution; they are, where standees are not permitted.

THE OPERATION AND MAINTENANCE OF THE MOTORBUS

BY J. B. STEWART, JR.[15]

ABSTRACT

AMERICAN cities depend upon transportation for their development, the kind of transportation depending on the size of the community. Motorbuses alone could not handle the traffic of New York City; subways and elevated railroads are not needed in cities having less than 200,000 population. Each city must solve its own separate and distinct problem. It is doubtful whether motorbuses ever will supplant an existing rail-line that serves an industrial section in a city of more than 150,000 people. This question was debated recently in a certain city where it was considered advisable to replace a bridge on the line of the railway rather than incur the expense of purchasing motorbuses.

The motorbus has a definite place in every city. In large cities it can be used for limited-load service; in medium-size cities, as a feeder to existing rail-lines from undeveloped territory; in small cities, to replace railways that have become obsolete or would require large sums of money to be put into condition to operate efficiently and economically. In medium-size cities also, motorbuses are used when the cost of replacing track and paving would necessitate too great an expenditure of money. In Newburgh, N. Y., the entire transportation of the city is rendered by 22 motorbuses, which serve 30,000 people.

Inter-city operation has passed the experimental stage and is to be found in all parts of the Country, the routes varying in length from that of short suburban lines to 300 to 400 miles, as is the case in California. In urban operation persons usually prefer to pay a higher rate of fare to ride on rubber; the difficulty of obtaining suitable parking-space also influences owners of private automobiles to use their cars for pleasure riding and to rely on the regular service rendered by motorbuses and rail-cars in going to and from their places of business.

When competing with a rail-line an entirely new class of traffic seems to develop. In one locality the traffic over a motorbus system paralleling a rail-line required that the service be increased from hourly to 15-min. intervals, but the earnings of the rail-line were not appreciably affected.

Before the railway equipment companies will submit quotations on equipment for railway lines they demand full information regarding the details of the service to be rendered. If this is not forthcoming no quotations can be obtained. Comparatively little study has been given to this matter by motorbus companies and much equipment has been installed that is unsuitable for the service that is expected to be performed.

But some operators are unreasonable in their demands. It is practically impossible to build a chassis that will carry a 25-passenger motorbus with a capacity load at a speed of from 30 to 45 m.p.h. and still be able to pull the same load up a 5-per cent grade a mile long in high-gear. This would require either a very large engine or too high a gear-ratio.

The study of brake-rigging is important, for the large number of stops imposes severe strains on the braking system. Lighting conditions vary with the service, and equipment for this purpose should have careful attention. Maintenance is given too little consideration, it being necessary frequently to remove many other parts to get at the part to be repaired or replaced. Relining the rear-wheel brake-bands is a difficult task, necessitating the removal of the wheel to get at the brake-band. This operation should be simplified. The tire problem has been satisfactorily solved through the medium of tire mileage contracts in which the charge for tire service is made on the basis of the number of miles traveled multiplied by the rate per bus-mile that has been agreed on.

Difficulty regarding the application of chains in wet weather has been lessened by the use of reinforced cross-link chains. In the winter time 34x5-in. tires are used but, because of the greater mileage that can be obtained, 36x6-in. tires are preferable in summer.

Railway men prefer to make repairs over a pit. In the case of a motorbus, however, this has several disadvantages that are peculiar to the motorbus. Among these are the danger due to poisonous gases that are given off by the engine and sink to the bottom of the pit, and the water that is always to be found about

[13] Jun. S.A.E.—Designing engineer, Mack Trucks, Inc., New York City.

[14] Staff engineer, Public Service Railway Co., Newark, N. J.

[15] General superintendent, Youngstown Municipal Railway, Youngstown, Ohio.

a garage on account of washing, rain in the summer time and melting snow and ice in the winter. Even though adequately drained the pits are always left wet. These difficulties are overcome by lifting the motorbus above the floor by an incline leading to a skeleton track, by raising the motorbus by jack-screws placed underneath the corners or by hoisting the motorbus to a concrete pier by a chain-hoist.

Ventilation must be provided to remove foul air from inside the motorbus during the cold weather and at the same time keep out rain. For heating, a system similar to that used on steam-railroad passenger-coaches has proved satisfactory.

The standard commercial-vehicle chassis formerly used for motorbuses have given way to special designs; the future development of the industry will depend largely upon the men whose duty it is to design and build the chassis and the body.

THE DISCUSSION

F. C. HORNER[16]:—After all, the acid test of what our vehicle will do is only found through practical experience in actual operation. To meet the requirements, we must know exactly what they are. It is only from such men as Mr. Stewart that we can learn how to furnish vehicles that will satisfy the riding public. How does Mr. Stewart get the ratio 1 to 5; that is, one spare motorbus to each five motorbuses?

J. B. STEWART, JR.:—That ratio is the result of our experience. Possibly, as the motorbus chassis is perfected, the ratio may be increased say to 1 to 7, 1 to 8 or 1 to 9. We use the 1 to 5 ratio to take care of our maximum load.

Mr. Horner mentioned the acid test of practical experience. It seems to me that, if the chassis builders expect to get a real job, they must put it out in actual service rather than try out new plans with test drivers. To put a chassis out with one, two or three drivers and run 24 hr. per day sounds like a hard test because the drivers are going continuously. But they are accustomed to the job. If regular drivers, say four drivers in a day, are used, the chassis gets hard service. It seems to me that the proper way to test out the new devices is to have some operating company try them out. We will be glad to try them out, if anybody wants us to do so.

MR. HORNER:—In connection with the question regarding the 1 to 5 ratio for spare motorbuses, do you use the so-called unit system of overhaul and maintenance?

MR. STEWART:—Yes.

MR. HORNER:—Do you still use the 1 to 5 ratio to maintain your service?

MR. STEWART:—My understanding is that on only one make of chassis can a unit be taken out without taking out other parts.

MARK A. SMITH[17]:—Mr. Stewart has given the builders of the modern vehicles something very serious to think about. He said that they were more interested in having the salesmen get the orders than in what happens to the orders after they are secured. I think that we had better sell motorbuses more as transportation engineers than as salesmen. The larger organizations that build such vehicles function through distributors, dealers and sub-agents. The successful motorbus organizations that keep their vehicles in service, a service of perhaps hundreds of thousands of miles with the same vehicles, using all kinds of drivers, distribute by selling from the factory to the organization that absorbs that vehicle and uses it directly.

This is a new field. Unless we sell the vehicles from the factory directly out of the front door, and through no sub-organization but into the hands of the operating company, we will not make the advances we should in the same length of time. We should get down to brass tacks, because motorbus service is a coming business.

The utilities commission of New Jersey, using tax data received in the various communities in 1923, reported 220,000,000 passengers carried on motor vehicles in that State; and New Jersey is not a big State. During the same period, the Long Island Railroad's suburban trains carried 68,000,000 passengers. In Newark, N. J., alone, the motorbuses operating in 1923, mostly competitive with other lines of travel, carried 92,000,000 passengers. This was in one city and is more than the entire suburban passenger travel on the Long Island system, as reported through the New York Public Service Commission. These are official figures.

We have a business of building and furnishing vehicles to these companies, which are actually begging us to give them something that will run and continue to run. If we drop the fads and fancies of building around some certain special thing on the vehicle, and build for service, we will uphold the reputation of the Society and the reputation of the entire automotive industry. If we continue to try to give these men vehicles that will not withstand the service and do not please the riding public, we will be a long time in getting the returns we should have.

MR. HORNER:—What is Mr. Stewart's opinion regarding six-cylinder versus four-cylinder engines for motorbuses?

MR. STEWART:—We have no six-cylinder engines and have had no experience with them.

MR. HORNER:—Have you formed any conclusions?

MR. STEWART:—We have no experience with them and I really cannot discuss the question.

MR. HORNER:—Have you had any trouble due to vibration and noise from the four-cylinder engines?

MR. STEWART:—Not if the rear-axle ratio is suitable. The builders realized that vibration exists, but they developed the correct rear-axle ratio and produced a smooth-running job.

MR. HORNER:—Even on long-distance runs does not the vibration bother your riders?

MR. STEWART:—No.

L. H. PALMER[18]:—I take issue with Mr. Stewart on the subject of tire maintenance. We changed to pneumatic tires on the single-deck motorbuses. We feel that there is cheaper maintenance in buying the tires ourselves than if we paid a flat mileage rate, as is done in Youngstown, Ohio.

I am interested in the way in which the electric railways and the manufacturers have approached the question of new equipment. The specifications and the character of the first equipments were not designed to meet the service. Perhaps, in the street-railway industry, we have not gone as far as we might from the standpoint of standardization. On the other hand, my impression is that the automotive industry has gone too far from the standpoint of standardization. In some instances, members of the industry are too "cocksure" that what they have to sell is right and they will not change soon enough.

The thought that Mr. Stewart projected into his

[16] M.S.A.E.—Consulting engineer, General Motors Corporation, New York City.

[17] M.S.A.E.—Vice-President and general manager, Royal Motor Coach Co., Inc., Rahway, N. J.

[18] Vice-President and general manager, United Electric Railways Co., Baltimore.

paper, I think, is one that our friends in the automotive business can very well consider seriously, because I doubt whether you can buy an engine that will perform well in city service at slow speeds and with frequent stops in heavy traffic and also in high-speed free-running interurban service, where the conditions of traffic are different. It seems that different types of chassis should be designed for two such radically different types of service.

I think the ratio of 1 to 5 for spare equipment is high. In Baltimore, we find it unnecessary to maintain such a high ratio. This may be due largely to local situations. Good street-railway practice demands that from 10 to 12 per cent of the equipment be out of service for all causes, such as overhauling in the shops, repainting, damage and running inspection and the like. We have come to the conclusion, although not a final one, perhaps, that say from 10 to 12 per cent of our automotive equipment is all that is necessary for out-of-service use, sometimes running closer than that when demands have made special efforts necessary.

W. P. KENNEDY[19]:—If electric-transmission motorbuses were available, the engineer would have equipment that is practically parallel in type and kind with what he is accustomed to in the street-railway system. The electric-transmission equipment consists of a generator connected to the engine and that is operated as a separate unit powerplant, not connected directly with the axle, and the energy generated by the powerplant is used electrically by a motor connected with the wheel. Therefore, from the standpoint of servicing equipment of that kind, the street-railway operator practically has men in his street-railway organization who are competent to do it.

Many things can be said on the subject of the value of this type of transmission from an acceleration standpoint. I think it has been proved beyond doubt, by the large fleets of equipment of this type which are and have been in operation for many years in Europe, that the actual running-costs, neglecting the overhead costs, are materially lower. They are in the neighborhood of 50 or 60 per cent of the maintenance cost of the change-gear equipment, particularly in cases where the stops per mile are frequent. The acceleration is as good as in a change-gear-transmission system and the fuel consumption, which has always been a moot point in this Country, has been proved to be equal to, if not lower than, the fuel consumption for a direct mechanical transmission. While we cannot talk about this subject from the standpoint of long actual running experience in this Country, about 1000 motorbuses of the gasoline-electric type are operating successfully in Europe and this ought to inspire confidence in anyone interested in the subject.

MR. HORNER:—With reference to gasoline-electric drive, although that type of vehicle has been operated for many years, it is, I think, still more or less of a curiosity. Moreover, it is my understanding that certain of the motor-vehicle operating-companies in England have made exhaustive tests regarding the advantages and disadvantages of gasoline-electric versus straight gasoline-engine drive, and have found that the former is 10 per cent more costly to operate than the latter.

THE GASOLINE RAILROAD-CAR FOR BRANCH LINES

BY W. L. BEAN[20]

ABSTRACT

GASOLINE rail-cars for branches of trunk-line railroads and for short-line roads have been the subject of much discussion since 1920. Mechanical officers of interested railroads, the engineers of companies building highway motor trucks and others specializing on this subject have now developed designs to meet the different service requirements. Several hundred cars of various types have been built and are in service. The railroad with which the author is connected has in operation or on order 24 cars.

Consideration of several principal factors of design is necessary if a selection is to result in obtaining equipment suitable for the particular service requirements of the carrier and if the knowledge accruing from the engineering development and operating experience of the past several years is to be of value. Important factors include:

(1) Horsepower rating of powerplant in relation to car speed, weight, grades, curvature and operating schedules; especially in the case of internal-combustion engines the power must be sufficient to permit engine operation at speeds and outputs well within the maximum of the engine

(2) Type of transmission between engine and wheels; to be simple to operate, accessible for repairs, rugged for endurance, quiet in operation and efficient in power transmission

(3) Single-end versus double-end control; the former is far preferable if terminal conditions permit, because it is cheaper to build, more reliable, has less weight and is easier to operate

(4) Distribution of available space between engine room, baggage room and passenger compartment. This factor is largely variable according to the ideas and the needs of the carrier. However, the convenience, comfort and safety of the passengers and the convenience of the crew require consideration because of the space available and the permissible weight

(5) Materials of construction are important and largely different from those usual in railroad equipment construction. Care is necessary to give lightness, strength, warmth, good appearance and quietness of operation at a permissible cost. Climatic conditions should be considered, as well as the more or less exacting requirements of the particular service

(6) Design of the car frame and body and of the trucks to give strength, lightness, good appearance and safe and quiet operation needs careful study and departure largely from usual steam-road practices

(7) Heating, signaling, lighting, ventilation and braking are all important factors con-

[19] M.S.A.E.—President, Kennedy Engineering Corporation, New York City.

[20] M.S.A.E.—Assistant mechanical manager, New York, New Haven & Hartford Railroad Co., New Haven, Conn.

cerning which experience has produced much information

(8) Multiple-unit control may be of some importance in later developments for specialized service but does not appear to be of considerable moment

The author has endeavored to give as much information from his own experience on these subjects as possible to help those railroad men and automotive engineers actively interested in the design of rail-cars to reach conclusions as to the best design of rail-car.

THE DISCUSSION

C. O. GUERNSEY[21]:—It is very appropriate that every so often we should have a general summing-up of the progress that has been made in a field as new as that of self-propelled gasoline rail-cars. It has been very pleasing to have Mr. Bean, as a result of his experience, pick out and designate some of the important features that should be taken into consideration in designing equipment of this sort. I am particularly pleased to have an opportunity to second what he has said regarding light-weight horsepower factors, means of judging performance and the various steps that must be taken to assure light weight in design. Every ton that is carried means that some 30 lb. of additional tractive effort is required on the top gear. When that is translated into horsepower, it means more weight and greater cost of operation, which, in turn, requires still more horsepower; the thing goes round and round in a circle so that, the lighter the car can be kept within satisfactory limits, the better it will be for all concerned.

Mr. Bean has set forth a list of what he considers to be the essentials. I should like to add one; it is that, on all unit cars, at least 50 per cent of the weight should be on the drivers. I have not always thought that to be the case. It is not the case, as I understand it, in regular steam practice; but those cars are light and they must go through storms and snow, so that it is very important that at least one-half the weight should be driving weight.

I would go a step farther than does Mr. Bean as to his means of comparing the performance of cars. Mr. Bean takes the weight of the car loaded and the horsepower of the engine, and from them derives a factor that is a key to their performance. If all cars were intended to run on the same railroad and on the same schedule, that method would be all right. But, in many places, the speeds that are necessary, on the New York, New Haven & Hartford Railroad for instance, could not be attained. So, to determine a true power-factor in matters of horsepower and weight, the speed should be taken into account. I have compiled Table 1, based on the tractive factor; that is, the tractive effort delivered at the rails, divided by the weight of the car in tons.

The tractive effort, in the case of the mechanically driven car, is determined by taking the torque of the engine at the particular speed under consideration, multiplying it by the maximum power-factor of the engine that can be counted on for regular every-day service, multiplying again by the gear-ratio and then dividing by the wheel-radius. It shows, when compiled, that the various cars listed on Mr. Bean's chart do not vary so widely as the mere weight-horsepower ratio would indicate. That is, cars of apparently lighter power that have been designed for lower speed, and for branch-line service in which fast schedules cannot be maintained, will show about the same power-factor or tractive-factor as will the larger cars.

Another point to be taken into consideration is whether the car has more than one so-called direct drive. If the car has two or more equally efficient driving-ratios, the higher one can be made rather high, so as to hold the engine speed down, as Mr. Bean recommends, while maintaining a relatively high car-speed. One can then drop the second equally efficient ratio for grades up to a certain limit; and, in case a third ratio is provided, can drop to that still lower ratio to take care of different conditions. The necessary data, with which to compile the tractive factor for all the cars listed by Mr. Bean, are not available, but I shall attempt to show how it works out for those cars on which I have the necessary data.

In explaining Table 1, I would say that, whereas Mr. Bean in each case used the maximum brake-horsepower, which often is at a speed beyond what really should be used, I take the horsepower that is obtained at the particular car-speeds shown in the various columns. The piston speed, roughly, is slightly more than 1200 ft. per min. for the different cars, depending somewhat upon the car. At any event, the horsepowers given are those that

[21] M.S.A.E.—Chief engineer, automotive car division, J. G. Brill Co., Philadelphia.

TABLE 1—RELATIVE PERFORMANCE OF J. G. BRILL CO. GASOLINE-DRIVEN MOTOR RAIL-CARS BASED UPON HORSEPOWER, SPEED AND WEIGHT

Model No.	Actual Horsepower at Given Speed	Weight Loaded, Lb.	Weight per Actual Horsepower, Lb.	Direct Drive					
				First		Second		Third	
				Speed, M.P.H.	Tractive Factor[22]	Speed, M.P.H.	Tractive Factor[22]	Speed, M.P.H.	Tractive Factor[22]
55	68 to 1,500	36,000	530	26.0	41.0	35.0	31.0	....	....
65	120 to 1,350	41,000	340	23.0	73.7	36.0	46.3	51.0	31.0
65 and Trailer	120 to 1,350	71,000	590	18.0	55.0	28.0	34.7	40.0	22.8
75	180 to 1,200	60,000	333	23.0	77.4	36.0	48.7	53.7	32.5
75 and Trailer	180 to 1,200	100,000	555	18.4	57.0	29.0	36.0	43.5	24.0
New York, New Haven & Hartford Railroad	120 to 1,350	49,800	415	23.0	60.5	36.0	38.0	51.0	25.4

[22] The tractive factor equals the torque times the efficiency divided by the weight in tons. In this instance, the mechanical efficiency is taken as 90 per cent and the load factor as 85 per cent.

obtain at the particular speeds at which each engine would run at the car speed set forth.

By reference to Table 1, it will be noted that the horsepower at given car-speeds with loaded car weight, the weight per given horsepower, and the tractive factor for the given weight and horsepower and for each of the various direct drives, are given. The performances of various cars are indicated and, in the case of models Nos. 65 and 75, performances with certain specific trailers designed for operation with these particular cars are given also. It will be noted that, for single-car operation, the tractive effort on top gear is fairly uniform for the various types of car, although the speed on top gear varies according to the service for which the car is intended. Naturally, when hauling the trailer, the performance factor is somewhat less, which means that we may either keep the same tractive factor at a lower speed, or the same speed with a lower tractive factor, depending upon the gear ratio. The figures given contemplate a change of gear ratio where trailers are used.

A. J. SCAIFE[23]:—Were the horsepowers cited by Mr. Guernsey taken at the point of highest torque?

MR. GUERNSEY:—No.

MR. SCAIFE:—The tractive factor is taken at the point of highest torque, is it not?

MR. GUERNSEY:—Yes.

MR. SCAIFE:—Then you will have a tractive factor higher than that given, if the maximum torque is taken.

C. M. MANLY[24]:—I have been interested in the subject of motor rail-cars for a considerable length of time, and also in hydraulic transmission. I have built some hydraulic transmissions; in fact, that is about all I was building for many years; so, I have had some experience with them. About a year ago we completed the design of a large motor rail-car, using a gear transmission that is in service now but on which the data are not wholly ready; that is, the persons who are operating the car are not yet ready to give them out.

The thing that attracted my attention particularly in Mr. Bean's remarks was the fact that this is the first time I have ever heard a railroad man mention the great value of alloy-steels. I am delighted to know that railroad men are beginning to appreciate the value of alloy-steels in reducing weight, just as automotive engineers have found them so necessary in their line of work; and it seems to me that the matter of reducing weight by proper construction and by the use of proper materials is of great importance.

Regarding hydraulic transmission, I was rather surprised at the efficiency given by Mr. Bean. It seems so low. I should have expected a higher efficiency. Just how it has been determined or just what the various points of loss are, I do not know; but I am sure that, so far as hydraulic transmission *per se* is concerned, an efficiency considerably higher than 69 per cent between the engine and the rim of the wheels can be obtained with hydraulic transmission. I made some tests in 1909 on a small car of about 50 hp. that was equipped with hydraulic transmission. At that time we were able to deliver at least 80 per cent to the wheels, and I am sure that can be done in the larger units.

I am certain that hydraulic transmission will give a much larger rate of acceleration than can be obtained with gasoline-electric transmission and certainly much higher than can be obtained with a clutch equipment. Of what importance that is on branch-line work, I am not prepared to say, not having the data, but I know that in 1909 in the operation of a gas-engine-propelled street-car, making 20 stops per mile and having an average speed of 15 m.p.h. including stops, we had to accelerate very rapidly and were able to do so with the hydraulic transmission.

D. W. FISHER[25]:—On the Reading Railway we have two Brill model No. 55 cars, but we are not in a position as yet to go into the matter farther, because no cars have been produced that are large enough to meet our requirements. Such equipment as we have is giving splendid results.

W. L. BEAN:—As near as I can recall it, the estimate of 69-per cent transmission-efficiency with the hydraulic transmission on the New Haven car is based on an 82-per cent efficiency in the hydraulic elements themselves. From that must be subtracted the reduction-gear losses, those between the gas engine and the pump element, the friction through the pipes, the loss through the spur gears on the axles and, of course, the loss in the car bearings. We have not the exact figures, but a summation of the several friction elements based on experience elsewhere, plus some brake tests, indicates that we are not very far wrong in that particular application.

Mr. Guernsey's table is of interest to us. It introduces a new thought in the relation between weight and power. Has Mr. Guernsey included in his new factor such things as wind resistance? Wind resistance is an important element concerning motor rail-cars, especially at the higher speeds, because it increases more rapidly than does the rate of speed in miles per hour and, at speeds of more than 35 m. p. h., is unquestionably a large absorber of power. We know also that, in all rail vehicles, in fact, in all rail transportation, there is a tendency for the tractive effort to decrease as the speed increases. I have not had a chance to study the table. The fact remains, however, that the tendency of the weight in relation to horsepower is downward. There must be something in it, or the tendency would not be from more than 600 lb. per b. hp., as it was in the case of the original prewar gasoline-electric type, to weights of less than 300 lb. per b. hp. in the current gasoline change-gear type of construction.

A MEMBER:—With reference to Mr. Bean's statement about wind resistance, Mr. Guernsey has ignored that entirely. In a car of average size, such as those used as rail-cars, he will find that 90 hp. is required to overcome the wind resistance at 60 m. p. h.; that the horsepower required to overcome wind resistance is exactly as the square of the speed; that, at 50 m. p. h. something over 60 hp. was required. I took measurements during actual tests; I did not make calculations from tables in the Society's books, but from actual tests.

MR. GUERNSEY:—What I have done is to take the actual horsepower obtained at a given engine-speed, corresponding to a particular car-speed, as shown for the particular gear-ratios. Then I took the torque that obtained at that particular speed, regardless of whether it was the maximum torque of that engine, and multiplied that by the mechanical efficiency, taking the load factor of the engine at 85 per cent of the horsepower shown on the curve, believing that in ordinary service an engine would vary by that amount. In this way I determined the tractive effort delivered at the rail.

I have made no effort in Table 1 to account for where the power goes, for how much is needed or for anything else. I have shown simply that, in the case of Model 75, for instance, the power-factor varies from 77.4 lb. per

[23] M.S.A.E.—Chief factory service engineer, White Motor Co., Cleveland.

[24] M.S.A.E.—Consulting engineer, Manly & Veal, New York City.

[25] Assistant mechanical engineer, Reading Co., Reading, Pa.

ton at 23.0 m. p. h., which roughly would give power enough for 3-per cent grades, to 32.5 lb. per ton at about 53.0 m. p. h. It is possible that the wind resistance may be high enough so that the car will strike a balanced speed at a point slightly below the speed shown. The rolling-resistance of wheels on roller bearings is much lower than the usual charts of rolling-resistance would indicate. On the other hand, the wind resistance is very high in proportion to the total horsepower, so that the wind resistance does become a very important factor.

A MEMBER:—I disagree with you again. I know from actual experience that a roller bearing takes more power above 35 m. p. h. than a plain bearing. A roller bearing, on the other hand, takes less power at slow speeds and starts more easily in winter; it gives greater pick-up and better acceleration, which are needed in rail-cars to make the frequent stops that are necessary. Therefore, we use roller bearings, not because they give better efficiencies at higher speeds, but because they give better efficiencies at the speeds at which we run and under the conditions under which we must operate. Consequently, power is needed at high speed, to overcome wind resistance and to overcome the extra friction of the roller bearings as well.

SOME NOTES ON AUTOMOBILE STAGES IN CALIFORNIA

BY F. D. HOWELL[26]

ABSTRACT

TRANSPORTATION by motorbus, although of recent origin, has advanced rapidly in its development, but is still undergoing a process of evolution. Less than 10 years ago, motor carriers were mostly "jitneys" and were heartily disliked by electric-railway officials. Now, motorbuses are developing a field of their own and are rendering a service not supplied by any other transportation agency, two of their most valuable functions being the building up of new territory and acting as feeders to established lines in the more thickly settled areas. The first steps in their development took place while engaged in local service but the trend toward interurban business soon became manifest.

In California, within the last 10 years, the interurban business has increased from that of a few isolated individuals to the operating of approximately 1000 vehicles, which cover the entire State and in 1923, carried about 25,000,000 passengers. The service rendered by automobile stages is divided into three distinct classes: (*a*) local city-service, (*b*) local intercity-service and (*c*) through-intercity service. Many manufacturers have endeavored to build what they call "stage chassis," having in mind their possible adaptability to freight service. But the requirements of passenger service differ greatly from those of freight service and a special type of chassis is necessary. These requirements are described in detail.

Many parts of the equipment should be improved. The braking systems at present in use are said to be entirely inadequate. Data are given concerning the wear of both the emergency-brake and the foot-brake linings. Wooden wheels have been unsuccessful, but when cast wheels are used the wheels should be cast without the hub and the hubs fitted to them. Troubles due to the use of dual rear-wheels are being overcome.

In the opinion of the author, sufficient study has not been given to the tire problem. The products of different tire manufacturers do not match. Different makes of tire should be made interchangeable and the same size of tire should be used for the whole fleet. To get the longest life from a tube, the suggestion is made that a size should be selected that will just fill the casing before sufficient air is put into the tube to stretch the rubber. In such a tube the tread will not stretch "paper thin" and will not be easily punctured.

In the stage and motorbus business the heaviest expenses are those due to (*a*) obsolescence of bodies, to keep abreast of the times; (*b*) the reconstruction of stock chassis, to make them conform to stage needs and (*c*) maintenance. Reconstruction of bodies is necessary because new cars must be modified to meet local conditions. One modification usually involves another. On rebuilt cars the annual maintenance cost amounts to more than 60 per cent of the cost of the new equipment.

The statement is made that if manufacturers do not pay more special attention to stage equipment and prepare themselves to fill buyers' specifications, general assembling plants will spring up, or stage companies will be forced to expand their present plants to complete the assembling.

THE DISCUSSION

F. C. HORNER[27]:—If the engineers of the society would give more time and thought to the study of the requirements of the users and of the riding public, they would get farther in shorter time toward finding the true answer to what the motorbus of the future will be. They should take into consideration all the various phases of motorbus design and operation that we have been discussing: Four-wheelers and six-wheelers; four-, six- and eight-cylinder engines, brakes, clutches, transmissions, bodies, lights, seats and all the things that have a part and are a factor to a greater or less degree in the kind of transportation facility that we are endeavoring to perfect.

The proper way for the engineers who are designing the motorbuses that we are selling to users, is to follow to a logical conclusion their suggestions and progressively thereafter, to make personal investigation to see what can be done, without too much capital investment, to meet their requirements. From a manufacturing standpoint, it is impossible to do all the things that users would like to have done. We all realize that. Nevertheless, we can do a little bit here and there and attack the matter in a constructive way, not attempting to make one type of vehicle serve four or five different purposes. The greatest mistake that we, as manufacturers of commercial motor-vehicles, have made, is to try to take a merchandise carrier and convert it into a passenger carrier. But we are getting away from that very rapidly.

CHAIRMAN A. J. SCAIFE:—Mr. Horner has touched on a true point. It is true that manufacturers are perplexed as to just what different operators require. The only thing that we can do is to get a composite picture of the whole situation. It is interesting to go from one operator to another, and hear one say, "You could not give me a 32-in. tire." Another will say, "I would not have anything else," and so on down the line, with reference to the cylinders and other parts of the vehicle.

[26] M.S.A.E.—Vice-President and assistant general manager, Motor Transit Co., Los Angeles.

[27] M.S.A.E.—Consulting engineer, General Motors Corporation, New York City.

One of the interesting features in connection with motorbuses, coaches, stages, or whatever we call them, is the construction of the body. I was interested recently in checking up some of the weights. Vehicles weighing from 9000 to 11,000 lb., and carrying from 18 to 22 passengers, about 4000 lb. of load. We make motortrucks weighing 10,000 lb. that carry 18,000 lb. of merchandise. So, considerable remains to be done with reference to motorcoaches; and the body has a large part to play.

H. D. HUKILL[28]:—Mr. Howell's paper on motor stage operation in California contains considerable food for thought for both the operator and the designer of motorbuses, particularly as the data presented are founded on the actual results and experience of fleet operation.

The figures for the average life of fabric brake-lining on two systems, 2930 miles for the service brake and 5850 miles for the hand-brake on one route, and 4970 miles for the service brake and 11,550 miles for the hand-brake on a second route, are representative of the mileages being obtained on fabric-lined brakes on motorbuses throughout the country today. Many cases are on record in which service brakes require relining at 2000-mile intervals. The cost of brake maintenance under such conditions is excessive and entirely out of proportion to the maintenance charge on other units. This factor, combined with the fact that the coefficient of friction of fabric linings varies greatly with conditions of temperature and of moisture, making them unreliable for use on down-grades and on wet or snowy roads, has led to the development, by the company with which I am connected, working in conjunction with leading chassis and axle manufacturers, of a metal-to-metal air-operated brake.

In this brake, two internal-expanding brake-heads are used per wheel, the heads being hinged at one end and expanded at the other end by a 180-deg. constant-lift cam. The camshaft is operated by an airbrake chamber, similar in its action to that of a piston and a cylinder, that is attached to the axle-housing direct. Two brake-chambers are used, one for each wheel, and brake adjustment is secured by merely turning a nut on a worm-and-wheel-type slack-adjuster interposed between the brake-chamber and the camshaft connection. A ⅜-in.-thick steel-liner or brakeshoe is bolted to each of the brake-heads, and the brake-drum is also lined completely with a two-piece liner, ⅜ in. thick, either bolted or riveted to the drum. With this construction, the actual braking-surfaces are both readily renewable inexpensive metal liners.

This brake equipment was installed in January, 1923, on 11 Fageol coaches, operated in street-car service in Everett, Wash., by the Puget Sound International Railway & Power Co. These same cars, with fabric-lined rear-wheel service-brakes, had averaged 3000 miles between lining renewals and 15,000 miles between drum renewals. After the installation of the metal brake-equipment, the brakeshoe life averaged 15,000 miles, which is the equivalent of 64,000 full stops from a speed of more than 20 m.p.h. on cars averaging in weight, with load, more than 14,000 lb. Since that time the demand for metal brakes has spread rapidly throughout California and the East, especially on motorbuses operated in city street-car service, inter-city coaches on grade routes and double-deckers.

Present experience indicates that the average life of the metal brakeshoe is from 10,000 to 15,000 miles, and the average life of the drum liner from 30,000 to 40,000 miles. Cases are on record in which the life of the shoe has been as low as 5000 miles and in others has been in excess of 50,000 miles. In most of the present metal-brake installations, the hand-brake and the service brake operate on the same set of brakeshoes; hence, the above figures on the life of the lining represent a total life for both the hand and the service brakes combined. Experiments are now being made with different lining-materials to increase the life of the lining. The advantages of metal brakeshoes, briefly summarized are:

(1) Greatly reduced brake-maintenance cost
  (*a*) The life of the lining is increased from three to sixfold
  (*b*) Lining replacements are made more cheaply and more quickly than with fabric linings
  (*c*) The earning power of the motorbus is increased, for the total time per year required for lining renewals is greatly decreased
  (*d*) The periodic replacement of worn brake-drums is avoided, for the drum liners that take the wear are renewable

(2) Greater safety and reliability
  (*a*) The coefficient of friction between the metal surfaces in braking contact is constant, regardless of the conditions of moisture or of temperature
  (*b*) The braking ratio is constant and is not affected by the adjustment of linkage, toggles and the like, nor by the friction of the pins, the yokes and the connections in the ordinary brake-linkage system
  (*c*) The brake adjustment is simple and positive
  (*d*) The operator is relieved of the fatigue that accompanies the use of mechanical brakes and is more alert for his other duties

(3) Greater average speed and decreased maintenance of other units
  (*a*) Because of their satisfactory operation at higher temperatures and their greater heat-radiating ability, the motorbus can safely be kept in high gear even on long mountain down-grades, and can maintain a higher speed without the crankcase-oil dilution and other evils that accompany the use of the engine as a brake in low gear

R. E. PLIMPTON[29]:—In discussing the general requirements of passenger service, Mr. Howell says that the stage must be able to operate 18 hr. per day. Does he assume that the other 6 hr. would be available for routine repairs and adjustments, or would the vehicle be taken out of service for a day at regular periods for such work? It would be interesting, I think, if Mr. Howell will explain what he considers good practice with regard to the time required for maintenance. How many days a year should a motor vehicle devoted to mass transportation of passengers be ready for service? How would Mr. Howell distribute the time off for repairs or overhaul during twelve months?

In discussing the requirements of various classes of service, Mr. Howell indicates that the maximum seating-capacity of city motorbuses should be from 28 to 30 passengers. This applies, obviously, to a single-deck vehicle; but it seems to me that the double-decker should have a place here and, possibly, a single-decker with a much larger seating-capacity.

What Mr. Howell has referred to as "inter-city local service" is worthy of comment. This form of service has led to the construction of a motorbus with a dis-

[28] M.S.A.E.—In charge of the automotive division, Westinghouse Air Brake Co., Wilmerding, Pa.

[29] M.S.A.E.—Associate editor, *Bus Transportation*, New York City.

tinctive body, that gives promise of encroaching to a considerable extent on what the author terms "intercity through service." In fact, many routes from 40 to 50 miles long are now being operated with a front-entrance vehicle having a narrow center-aisle and medium headroom. All these are characteristic of the second type of vehicle referred to in the paper. The governing factor, as between this vehicle and the sedan type with multiple side-doors, is the frequency of passenger interchange. On many lines operating through thickly built-up sections, in which passengers must be taken on or dropped frequently, it has been found that sedan construction takes up too much time and that fare collections are troublesome to the driver; the result has been a distinctive type of motorbus construction.

Mr. Howell's comment, that a vehicle for local intercity service must be designed for operating over unimproved roads, deserves careful consideration. Is it the best thing for all concerned that the type of design should be determined by the necessity for detours? As Mr. Howell indicates later in his paper, the engineer has a real task to perform in satisfying the requirements of motorbus transportation; consequently, the highway department should be responsible for a certain standardization of highway conditions. Even though roads must be rebuilt or repaired, one side should be kept open or a detour provided that will give service comparable with that of the improved highway. I realize that this is more an ideal than a practicable matter in some cases, but many state highway departments are giving more and more consideration to the providing of better detours.

Accommodation for baggage, which should include the light parcels carried by passengers, is not mentioned to any extent in the paper. The practice seems to vary in different parts of the country. A place might be provided on the roof; at the extreme rear, that is, outside, in a boot or rack; or at the rear, inside the body. Then, too, the space beside the driver might be used; and this is favored by some persons inasmuch as the driver can keep his attention on the road all the time, instead of being distracted by passengers alongside him in the same seat. It is the duty, certainly, of a motor common-carrier, to accommodate, in some way, the personal baggage of passengers. It may be expedient also to carry light express packages, either in a combination vehicle, or in a separate motor truck. What does Mr. Howell consider to be the best way of doing this work, on long-distance lines such as have developed in large numbers in his own State?

Much might be said on that part of the paper devoted to the important vehicle-parts. The auxiliary transmission described is probably a special requirement for operating in mountainous country. Even so, was it necessary to go to the additional expense of a separate set of gears? At present, I understand, a single transmission is available for giving the extra reduction required on 27-per cent grades.

Mr. Howell has demonstrated the need of better brakes. Has he experimented with front-wheel brakes, not so much for greater retardation, as for giving a larger area of brake-lining; if so, with what results?

One of the striking things in Mr. Howell's paper is his statement regarding city operating conditions. If the usual condition is that preparation to stop must be made at about the time that the maximum speed is reached, an opportunity is presented for a closer engineering study than has as yet been given to this subject. If the free-running time, or the time during which the route can be covered at the maximum speed, is cut down to zero, the only way by which to maintain a fair schedule-speed is by improving the acceleration and the retardation characteristics of the vehicle. What does Mr. Howell consider to be the maximum rate that can be used for both these factors, having due regard for the comfort of the passengers? Further, has the maximum been reached with present forms of transmission and of braking systems? What are the possibilities of improvement through the use of four-wheel brakes, say, and of a substitute for the present method of mechanical gear-changing?

Finally, referring to the discussion of the obsolescence of body types, Mr. Howell says that bodies in first-class condition are abandoned to meet the demands of the public and to keep up with advances in the art. It may be difficult to separate these two factors; but at least part of this difficulty should be credited to the operating companies themselves. To a considerable extent, they have led the way and have thus created a demand. They have increased the comfort qualities and the convenience of their rolling-stock, to the satisfaction and the appreciation of the public, with a gain in patronage. This has happened frequently, so that the cost of developing and holding new business should not be considered merely as an expense caused by advances in the art.

S. P. THACHER[20]:—I cannot, of course, speak for other tire manufacturers, but so far as the United States Tire Co. is concerned, Mr. Howell's analysis of tube size with respect to casing size must be questioned. We design our tubes in all sizes as large as is consistent with proper fit and ease of mounting, with the tube rounded out to shape with air. We believe that a tube larger than ours in sectional size would sit too far down on the beads and would probably be pinched in mounting. We use a very thick heavy molded flap that occupies considerably more space than do the flaps used by other tire manufacturers. It is impossible properly to fit one of our 36 x 6-in. tubes in one of our 34 x 5-in. Royal Cord truck-bus casings. The tube more than fills the casing and buckles so much at the rim surface that, when the flap is in place, the tube would soon pinch itself.

I do not wish to take the position that present tires and tubes are the last word, particularly with respect to casings and tubes for motorbus service. This field, which is opening up so rapidly and is so immense and of such potential size, is worthy of all the attention that tire engineers can give to it.

A. F. MASURY[21]:—I believe that Mr. Howell's presentation of the development of motorcoach activity in California offers considerable food for thought to automotive engineers and motorcoach manufacturers. Under the heading of Brakes, Mr. Howell mentions some of his troubles with these parts and submits actual service figures. The life of brake-linings appears to be very low. The unit brake-lining pressure is not limited to 12.5 lb. per sq. in. for all linings, for some give much greater wearing-quality with twice this pressure. The use of better brake-lining material with ribbed carbon-steel drums has proved to be highly satisfactory for motorcoach work.

Mr. Howell does not mention the clutch. Has he experienced any trouble with it? Is the life of the friction-discs satisfactory?

I am inclined to think that the metal disc-type wheel

[20] M.S.A.E.—Technical director, tire manufacturing department, United States Rubber Co., New York City.

[21] M.S.A.E.—Vice-President, chief engineer, International Motor Co., New York City.

is more advantageous for motorcoach work than is any other. It is lighter for the same strength, cheaper to manufacture, and has a better appearance.

I think Mr. Howell will agree with me when I say that today real motorcoach chassis are being produced and that the period of individual evolution has become a thing of the past.

A. E. HUTT[32]:—In his opening remarks about the evolution of the motor-carrier industry, Mr. Howell states that a very special class of equipment has been developed for interurban service, yet in his concluding remarks he states that the industry cannot be expected much longer to purchase stock chassis and alter them to suit the service and, further, that if manufacturers do not give to the service a chassis complete for all purposes, the transportation industry will be forced to assemble its own chassis. If Mr. Howell means that transportation companies are still forced to purchase truck chassis and remodel them to suit motorbus requirements, I would like to call his attention to what has been accomplished by bonafide motorbus builders in this country. At the American Electric Railway Association convention, held recently at Atlantic City, there were shown types of vehicle to suit the requirements of all parts of the country. If Mr. Howell is looking for a universal type of motorbus that will be suitable for all types of service, city, interurban, intercity and the like, I am afraid that he is looking for the impossible, at any rate at this period of the development of the art. Motorbus manufacturers certainly cater to the requirements of the trade and are producing vehicles that are finished, in every sense of the word.

Mr. Howell's remarks about four- and six-cylinder engines, in which he advocates four cylinders for city service and six cylinders for intercity service on account of their greater flexibility, are rather at variance with the conditions. If flexibility is required anywhere, surely it is in congested city streets with the consequently numerous stops, starts and variations in speed, and not on the open highway where practically no stops are made and where the speed is almost constant. I believe in six-cylinder engines for all motorbuses, but if I must have both fours and sixes I would put the sixes into city service and the fours into intercity or interurban service.

F. D. HOWELL:—In his opening statement Mr. Horner meets the situation squarely and, with cooperation on the plan he suggests, no reason exists why operators and manufacturers cannot work together to their mutual advantage. Contact between the two should, however, be between their engineers rather than through non-technical salesmen, if one is to get at the facts regarding necessities and be able to separate the wheat from the chaff; for, as Mr. Scaife aptly says, there is a wide divergence of opinion among the operators themselves as to what they need. A great amount of this divergence is, however, based on personal likes and dislikes, with no experience or data to substantiate them, and this will have to be taken with a grain of salt in arriving at final conclusions.

Mr. Scaife says also that, considering the ratio of dead weight to pay-load on freight trucks, it is evident that something must be done to reduce the ratio for passenger cars, as they are much out of numerical proportion at present. I believe the ratio between the freight truck and its load can have no bearing on the ratio between the live and the dead load of passenger vehicles, as weight is a very great contributor to the comfort of passengers, and the comfort of passengers and the life of the vehicle are the two important points to be considered. Comparing our passenger equipment with that of the railroads, we are far ahead of them in this ratio; for instance, our 25-passenger cars now carry about 400 lb. per passenger, dead weight, while the lightest railroad passenger coach has about 1000 lb. of dead weight per passenger, and this runs up to more than 2000 lb. without taking into consideration motive power, that is included in the weight per passenger on the motor vehicles. With the present system of springs on motor-driven passenger-vehicles, it must be admitted that the greater the weight per passenger is, the less are road shocks felt by the passenger and the less swaying of the body there is when going around curves.

Mr. Hukill's description of his airbrake is very interesting and complete, and I believe he is on the right track with his internal-expanding brakeshoes. External brakeshoes on a brake beam, hung from the frame, appear not to be feasible, as a sudden clamping of the brakes under a reasonable speed on a heavy grade has a tendency to tear out the entire brake-beam rigging.

Before they can be generally adopted, either air or hydraulic brakes must have demonstrated their reliability under severe conditions and must also be reduced to their simplest form and admit of reasonably free road adjustment. Recent reports from operators who are using Mr. Hukill's brake are now coming in that claim very satisfactory results, and it may be that the brake will come into general use.

Four-wheel brakes, before they can be used on stage lines, must be proved out regarding the possibility of locking the front wheels on sudden application and preventing steering. With all the work now being done on brake design it would appear that we should have a brake for the stage business shortly that will reduce all our fears of failure.

I think that, as with Mr. Thacher's company, all the large tire companies are now endeavoring to make a tube that will fit the tire casing more nearly than heretofore. I am sorry Mr. Thacher did not express his opinion also on the question of standardization of overall dimensions of casings, because I believe that this is a necessity, for large users ought to be able to divide their orders among the large standard tire companies.

Mr. Plimpton asked why we did not use seven-speed transmission in our mountain equipment instead of the

[32] M.S.A.E.—Formerly general manager, Philadelphia Rural Transit Co., Philadelphia.

FIG. 1—LONG-DISTANCE CAR BAGGAGE-CARRIER
Showing the "Boot" for Carrying Baggage and Express Packages at the Rear of the Long-Distance Cars Having Side Doors

FIG. 2—STREET-CAR TYPE OF CAR

This Vehicle Is of 25-Passenger Capacity, but Due to the Necessity of Utilizing the Rear-Seat Space for Baggage and for Express Packages, Its Carrying Capacity Is Reduced to Space for 22 Passengers Only

double installation shown in the paper. The seven-speed transmissions now on the market require special bell housings and the like before they can be installed in the chassis, and these bell housings are not as yet available.

We have had no trouble with the disc clutches, but our experience has been largely with the White Motor Co.'s product. Disc wheels are of good appearance and the later models, I think, will prove more satisfactory than those of the spoke type.

The reference in my paper to a preference for a four-cylinder engine on local work and a six-cylinder engine on the inter-city through-work was intended to indicate a preference for the four-cylinder engine on account of economy of maintenance and operation; but, on inter-urban through service, where hills or mountains are encountered, the six-cylinder engine permits of ascending long grades in second speed, on which, with the four-cylinder engine, we would need to resort to low gear, which is tiresome and annoying to the passengers.

Mr. Plimpton asks questions that possibly should be covered in a separate paper from this, but I will endeavor to give brief answers to his queries. Express matter and the baggage of passengers are handled on long-distance cars by constructing a boot at the rear of the side-door cars; and, on the local 25-passenger street-car-type cars by constructing pockets in the side skirts and under the body. This and the use of the seats and a rack constructed on the front fenders, so that suit-cases and baggage can be stored between the rack and the hood of the engine. Some operators carry the baggage on the roof of the car as shown in Fig. 11 of my paper. This has its disadvantages, however, in that it adds to the weight of the car to build a top that will carry baggage, and makes the handling of baggage more difficult at intermediate stops, since the driver must climb to the top and sort out from the pile up there and requires extra help when loading, or unloading.

The company I represent does a fairly large express business in addition to handling baggage. Its thought in developing the express business was that it could load up its cars with express matter and thereby pay the expense of carrying empty seats on local runs and provide more pick-up space for passengers than it could without this revenue. As this express business developed, it was found that the peak-load of express corresponded with the peak-load of passengers; it then put on express cars that ran on a schedule, which carried these peak-loads of express and relieved the passenger cars when loaded. These express cars also acted as service cars between the main shops and outside shops and stations, and it was thought this express-car service would develop so that we could afford later to carry trunks free and thereby render complete service to a passenger. About this time the American Railway Express Co. became excited over what would happen to its business if our company continued to develop its express business. In a heated fight before the Railroad Commission, it either out-argued us or out-pleaded us. The result was that the Railroad Commission ordered us to discontinue the use of our express cars and to confine our express activities to the transportation of parcels that weigh 40 lb. and less, on passenger cars only.

This order put us up against it to take care of peak-load service for passengers and express, and is forcing us to relinquish the last seat in the 25-passenger cars, reducing a 25-passenger car to a 22-passenger car and using the space occupied by the last seat for the storage of express and baggage. Fig. 1 shows the boot in the rear of the long-distance side-door cars for baggage and express. Fig. 2 shows the side-view of a 25-passenger cut down to be a 22-passenger car, through the space occupied by the rear seat being used for baggage and express. Fig. 3 shows the rear view of this compartment, illustrating the double doors for express and the small pockets on each side of the express space for spare tires.

With regard to obsolescence of body, Mr. Plimpton is correct in his statement that this is really a development expense rather than a straight operating-expense; but, at the same time and in the last analysis, all expense must come out of operations. Body obsolescence comes from the desire of the operators to meet the needs of the public in the fullest manner, and to give them the most comfortable transportation that is available. Aside from this, obsolescence occurs when a competitor puts on an improved type of body. Theoretically, this obsolescence charge should be carried to an obsolescence fund, and distributed over a period of years; but it is really immaterial, so far as the company is concerned, whether it charges the obsolescence to the year in which the body is scrapped, even to the extent of showing the balance sheet in red, or whether it is charged off for a period of years, because the company loses that money and, unless the obsolescence charge is used as a basis for an increase in

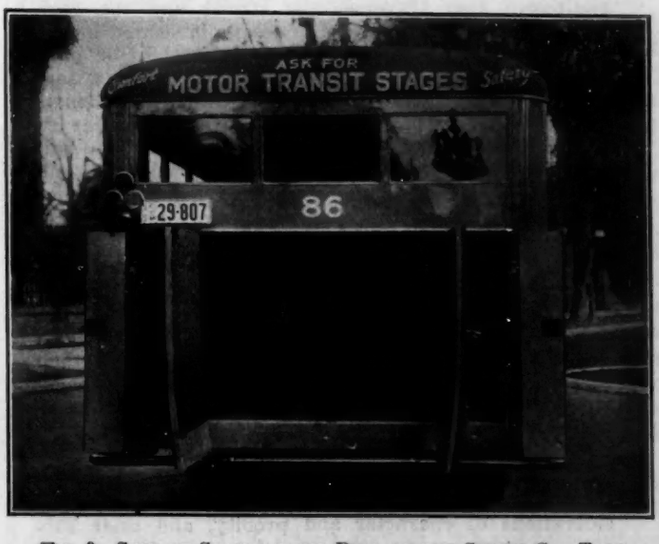


FIG. 3—STORAGE SPACE AT THE REAR OF THE STREET-CAR TYPE MOTORBUS

Showing How the Rear-Seat Space Is Utilized for Baggage, Express Packages and Spare Tires

rates, the public does not suffer any by reason of so charging it off.

On the subject of a rate base, however, there is no question in my mind that a period should be set in which all the cost of development should be allocated and charged off, so that the whole amount does not fall in a short period, thus involving an increase of rates to cover, with the consequent more than fair return that would accrue when this development expense has been paid for, unless the rates were again reduced.

On our fleet maintenance we have found that it involves minimum repairs or adjustments at the time that they are discovered, and general overhaul at regular intervals. We bring every car into the shops for 24-hr. overhaul every 10 days. This means that the car is supposed to be in service approximately 332 days out of the year. In addition to this 24-hr. overhaul period, we have 6 hr. each night to make adjustments or minor repairs; and, with service-men in all terminals to make adjustments found necessary at the end of any trip, we keep the whole fleet in good condition. We have many items of replacement worked out to a fairly close length of life, such as wheel bearings, brake-linings and engine valves, so that we know just about what to pick out at any 6-hr. interval or what to go after on the 24-hr. intervals. We keep very accurate mileage records on cars, and a very accurate list of all work done on parts, especially on renewals. These are all entered on large sheets that are posted in the shops so that the shop foreman can turn to any car and see when any unit was last changed or just what has been done to the car prior to the particular time at which he is investigating.

Double-deck buses have only come into use on the Pacific Coast within the last few months, when the street railways installed a few in their local service. They are necessary when used for street-railway service in congested areas.

The length of cars, quoted as 30 ft., is based on the turning radius in congested areas in streets of from 40 to 60-ft., width between curbs, with traffic buttons at the intersection of the center line of streets. A 30-ft. car can make the quarter turn if well to the right of the center and, if traffic buttons are on the property-line intersections with street center-lines, can do so readily and still leave room for the passage of opposing traffic; but a car much longer than 30 ft. will need to jockey to get around these corners, thus adding greatly to the congestion and delay to other traffic. We have a few 50-passenger single-deck "rubber-neck wagons" in Los Angeles and they completely block the traffic in both directions on each of the intersecting streets when they have to negotiate a right-angle turn.

SMALL-CONSIGNMENT COMMODITY-DISTRIBUTION IN LONDON AND ITS ENVIRONS

BY JAMES PATERSON[33]

ABSTRACT

POINTING out that London is the social and economic center of the British Empire and describing its port, its transportation needs and facilities and those of its environs, the author traces commodity movement from ships to lighters and to warehouses, from warehouses to stores, from stores to homes, to the surrounding towns and to country districts, and gives details of the distribution and collection system developed and operated by the company he represents, a system employing horse-drawn and motor-vehicle equipment that traverses the streets and the highways. Major divisions of the details presented include statements regarding the nature and weight of packages, segregation of the territory into districts, sorting depots and transfer thence to delivery depots, direct deliveries, store-door delivery and the time required for delivery. The service offered by the railroads is also treated. Other features mentioned briefly relate to statistics of the street and highway service, the various zones, the charges, clerical methods and personnel.

Plant equipment includes horses, horse-drawn vehicles, and gasoline-driven and electrically driven trucks. The gasoline-driven transfer-trucks have detachable bodies, as have the trailer trucks that are operated with them. The electric trucks and their service receive consideration, and the types of vehicle most needed for the future are outlined. The buildings and platforms are of simple design, the chief need being yard space well paved and fenced.

A feature of the service that is emphasized relates to the careful selection of the employes, based on considerations of character and probity, and their subsequent training while employed. Reference is made to the very limited duties that the horse will perform when the conversions from horse-drawn to mechanical transport now contemplated are made, and advice concerning how far such conversion should proceed is solicited.

THE DISCUSSION

F. E. WILLIAMSON[34]:—Prior to 3 or 4 years ago, the railroads in this country were not utilizing trucks to any considerable extent. Recently, a great amount of experimenting has been done with a view to supplementing rail haul. For example, on the New York Central Railroad, we have discontinued the way-freight service on the electric division south of Croton and North White Plains, about 32 and 25 miles out, respectively; are consolidating at Yonkers freight for that territory originating at New York City and in the West; and are there sorting out freight for various truck routes, as has been outlined by Mr. Paterson as his practice. These trucks run to the various stations on the line of the route, discharging what freight they take on the out-bound trip and picking up what we call westbound freight on the return trip, bringing it back to Yonkers, where it is consolidated into through-cars for destination or for break-up points at some distance. We think that this arrangement is desirable, not only because we think we are saving some money, but because we are saving the interference caused by way-freight trains on as busy a railroad as is the New York Central.

We have also gone into the use of trucks somewhat, in connection with lighterage service at New York City. We are trucking from the Manhattan side practically all the coastwise freight, in carloads, direct to the coastwise lines, in lieu of lighterage. We have always trucked less-than-carload coastwise freight. We are also truck-

[33] Director, Carter, Paterson & Co., London, England.

[34] General operating superintendent, Buffalo and Eastern Lines, New York Central Railroad, New York City.

ing certain single-car or split-lot shipments of export freight to the steamship piers in lieu of lighterage deliveries and have extended that service not only to the Manhattan piers but to South Brooklyn and other outlying points. We find advantage in the freeing of our lighterage terminals, in more expeditious delivery, and in the fact that we do not have to use a tug and lighter to handle small shipments. In some instances, in the days when we were lightering split-lot shipments, and lightered, say, one box of sausages that weighed 210 lb. from Weehawken to South Brooklyn, we might better have hired a taxicab.

The Erie Railroad has made considerable use of trucks, its practice being to load a large number of cars that contain freight for delivery in New York City, at the Jersey yards. By the use of semi-trailers, that freight is loaded, brought to Manhattan, and either delivered at inland freight-stations or, if the consignee so elects, an arrangement is made by the consignee with the trucking company, under which the haul by the trucking company is extended beyond the obligation of the Erie Railroad, and store-door delivery is made. This, I think, has proved to be, in most respects, a satisfactory arrangement.

We have not been able to work out a satisfactory store-door plan, but considerable discussion has taken place looking toward that end. Commissioner J. S. Harlan, of the Interstate Commerce Commission, spent a year or more here in 1916 or 1917 in an endeavor to work out some such plan. But our difficulty is that we find that we have, say, a carload of apples consigned to some man having an office on the 27th floor of the Woolworth Building, and that is all he has; and we do not know where to deliver the apples. So, store-door delivery, from our point of view, did not work out. Too many persons, apparently, are making our piers their principal places of business. They have nothing except a telephone. It must be that conditions in and about London differ from ours in that respect. Every one there must have a place to which freight can be delivered, which certainly is not true here.

Mr. Paterson spoke particularly of the number of lighters in the Port of London, 12,000 lighters. Are those lighters of large capacity, or are they small boats?

JAMES PATERSON:—They vary in capacity from 70 to 150 tons, as a rule.

MR. WILLIAMSON:—How are they propelled?

MR. PATERSON:—By tug.

MR. WILLIAMSON:—And a tug would be assigned to each boat, with as little as 70 tons capacity?

MR. PATERSON:—No; several boats are towed together.

MR. WILLIAMSON:—Is not the congestion on the streets of London so great as to interfere with the delivery, as it certainly is in New York City on certain streets, which is made apparently so satisfactorily by trucks?

MR. PATERSON:—No; it works. I have not seen New York City sufficiently as yet to compare the two cities as regards traffic congestion, but I notice that the traffic congestion in New York City is mostly confined to a certain part of the city; I think our traffic is more spread out. Therefore, we do not experience difficulty or serious delay in making delivery by our vans.

MR. WILLIAMSON:—Do we understand that your deliveries and pick-ups are all made during working hours, or do you operate at night also?

MR. PATERSON:—We must do the collecting and delivering during working hours; but a great part of the transferring from point to point is done after working hours when the streets are empty.

MR. WILLIAMSON:—Do I understand that, if a shipment weighing 70 lb. moves from Edinburgh, for example, to London, destined for Croydon, it is trucked from London to Croydon and that the collection-and-delivery charge is included in the rate?

MR. PATERSON:—Croydon, of course, is some distance from London. Assuming that the railroad hands the shipment to somebody else to deliver at Croydon, the delivery charge would be according to Table 1 of my paper.

MR. WILLIAMSON:—But the charge would not ordinarily be included in the rail rate?

MR. PATERSON:—Yes. If the man at Edinburgh paid a collection-and-delivery rate to Croydon, the package would be delivered at Croydon, but the rebate that a trucker would get, if he said that he, instead of the railroad, would make the delivery, would only be the Croydon rebate, because a rail station is situated at Croydon to which the railroad could send the package if it so wished.

MR. WILLIAMSON:—I notice that the rates shown in Table 1 of your paper apply only to smallweight shipments. Do I understand that you will also truck carload shipments? For example, if you had a carload of machinery, would that be handled for store-door delivery in the same way as small shipments?

MR. PATERSON:—Yes; except that if, say, a 4-ton load of machinery were handed us to truck from point to point in London, we should not trans-ship it. It would stay on the truck that collected it, which would deliver it; and the rate would be a continuance of the rate of the smaller packages, and would be proportionate to the much less expensive form of transport that we were asked to undertake.

F. C. HORNER:—As I understand it, Mr. Paterson does not see the necessity of having cartage control for determining the location of the vehicles while they are in operation during the day, but believes in handling the traffic and taking care of the disposition and location of his vehicles in some other way. How can we avoid having some form of cartage control?

MR. PATERSON:—My criticism was that it is unnecessary for a senior official who has under him several depot managers to know too much of the detail of the depot managers' workings; so long as the depot managers' workings are efficient, I think it does not matter, broadly speaking, to the senior official whose duty it is to superintend the department manager where each individual truck is at any particular time. If it is proved that all the trucks are doing good work in an efficient manner, that is all there is about it. The other method involves unnecessarily detailed information that is too costly to obtain.

MR. HORNER:—For instance, suppose that one of your vehicles was on a collection route, and got a full load out of, say, 15 or 20 collection stops. At the eleventh stop, for illustration, suppose the driver found that he would have to pick up a 1000 lb., or perhaps a ton, which would throw the vehicle out of its schedule. If he took on the whole load, he could not clean up his other collections on time. How would you handle a case like that unless you had some system of cartage control whereby your car man could telephone and find out what to do; probably to have the controller slip in an extra truck and pick up the big load?

MR. PATERSON:—The truck driver would telephone to what I should call his depot manager; but what I maintain is, that the truck driver should not have to telephone to the depot manager's superintendent, the superintendent being the superintendent of several depots. The

form of cartage control that I was criticizing provided for a telephone call to be made not to the man's boss, but to the man's boss's boss. That, I thought, was wrong.

MR. HORNER:—Then you really have a system of cartage control, although not the system we were discussing.

MR. PATERSON:—Not a "superman" system. I do not believe in "supermen."

MR. HORNER:—But do you know where the vehicles are and can also switch them at will at short notice?

MR. PATERSON:—Yes.

MR. HORNER:—To what extent are your vehicles back-loaded; or, is it necessary to back-load your vehicles? In other words, is it necessary to get a load in both directions to assure a profitable operation?

MR. PATERSON:—Are you speaking of collection-and-delivery or point-to-point vehicles?

MR. HORNER:—If you send the vehicles out with a load; do they come back with a load? In what proportion?

MR. PATERSON:—The number of tons or pounds that a vehicle may carry is not always indicative of whether that vehicle is fully employed. The freight value of its contents may perhaps give a figure; you might have a case in which the number of pounds carried in proportion to the carrying capacity of the vehicle might appear to give a figure of inefficiency, whereas the freight value might really be very good indeed. I think that is the answer as regards collection-and-delivery vehicles.

As regards point-to-point vehicles, we find in London that, out of every four loads of goods sent out on transfer trucks, London eats the contents of one of those trucks and sends back three of them with what it has produced; in other words one truck returns empty out of every four that are sent out.

MR. HORNER:—That would cover the territory surrounding London, Croydon and other places?

MR. PATERSON:—Yes, except, of course, in the case of a town like Brighton. At certain times of the year every one is going there and, at other times, every one is coming back, so you get loadings of luggage in one direction only for a time and then in the other direction for another time. That means inefficient load-factors, which are balanced by making the charges proportional.

MR. HORNER:—In the movement from depots to warehouses to what extent does the motor vehicle assist in this operation, if it does assist?

MR. PATERSON:—Gradually, a certain proportion of the warehouses are being built away from the River, in a way that would correspond to that part of Fifth Avenue approaching Central Park in New York City; there, of course, the River not being available, motor vehicles are used largely in the movement of merchandise.

MR. HORNER:—The movement of goods from the country is largely by rail, as I understand it. Why are not motor trucks used more for this movement? Is it because rail transportation is cheaper, say, within a 25- or 50-mile radius of London?

MR. PATERSON:—Rail transportation appears to be cheaper outside that radius. The precise mileage of that radius varies according to the class of traffic. One of the reasons is that Birmingham, which produces ironware, and Manchester, which produces clothing, are both situated beyond what I believe to be the motor-truck radius of London for that class of traffic; on the other hand, much garden produce originates in the country around London, and often travels by motor truck.

MR. HORNER:—In that connection, is it true that they are beginning to bring milk to London by motor vehicle from the nearby surrounding territory?

MR. PATERSON:—Yes, but I should not like, without notice, to be asked to discuss the economics of it.

MR. HORNER:—But they are beginning to do it to some extent.

MR. PATERSON:—Yes, but whether the pendulum will not swing in the other direction soon is a question.

MR. HORNER:—Another point that you bring out in your paper is that the stores think more of quick service and advertising. Is it that this service is due to competition between the stores, and is it the one that gives the quickest service that gets the business from the consumer?

MR. PATERSON:—Yes. If it were not my duty to serve the public, I might venture to say that it is being rather spoiled by the excessively good service being offered to it, which, of course, imposes expense on those that serve it.

MR. HORNER:—The cards that you give to customers to put into their windows where your men can see them are used by both business and by private houses, are they not?

MR. PATERSON:—Yes; 480,000 cards are in use now.

MR. HORNER:—You mention that the trucks are habitually drawing trailers. To what extent do you use the two classes of trailer, the four-wheel and what you term the six-wheel type.

MR. PATERSON:—We have standardized the type of lift-body that I described; the trailer is merely a four-wheel steel dray on which precisely the same lift-body is carried as is carried on the 4-ton truck that draws the trailer, so that two standard bodies are drawn instead of one. For standardization reasons, we have never attempted a six-wheel trailer, because no six-wheeler can be built to comply with traffic regulations and carry two standard-size containers.

MR. HORNER:—As I remember it, a great many of your larger trucks have four-wheel trailers.

MR. PATERSON:—No; not a great many; a small proportion.

MR. HORNER:—In comparison with what four-wheel trailer operation you have seen in New York City, it might be termed a comparatively large proportion of the vehicles. You probably have not seen any four-wheel trailers in New York City.

MR. PATERSON:—No; I have seen no vehicles in New York City such as we use.

MR. HORNER:—Very few of them are used. On the question of depreciation of your vehicles, do you write them off after a certain length of time?

MR. PATERSON:—We write them off in approximately 7 years and the electrics in 11 or 12 years.

MR. HORNER:—And at the end of that time, if you still have a serviceable vehicle, what value do you place on it, if any?

MR. PATERSON:—A "break-up" value, but we then hope to make a profit for the next ten years by using it.

MR. HORNER:—Have you had an opportunity to check up whether the cost of electric current for charging your electric vehicles is more in England than it is in this country?

MR. PATERSON:—We are able in very special circumstances to get the equivalent of 2 cents per kw-hr. I should add that, to get that price, the consumer must study the producer's load-curve and agree to take current only at times when the curves would be assisted by his taking it.

MR. HORNER:—I noticed an editorial in the *New York Herald-Tribune* recently that referred to the number of horses that are being used; in part it is as follows:

Statistics tell a gloomy story to the horseshoer. In 1918, the number of farm-horses in the United States was 21,555,000. At the beginning of 1924, it was 18,263,000, a decrease of 15 per cent in 6 years. The falling off has fluctuated from year to year, but there is no prospect of halting the continuous decline. In the cities, there is less and less use for the blacksmith's anvil. In 1910, the Census Bureau reported the "number of horses not on farms" to be 3,182,789. In 1920, the number had been reduced to 1,705,000. More recent figures are not available. In New York City, there were 108,000 horses in 1917; now there are about 60,000. Only on the waterfront, where the congestion is terrific, are the horse and wagon found more serviceable for short hauls than is the motor truck.

As a matter of fact, I am not sure that the figures given in this editorial are authentic, but it seemed to me that, when I was over there looking about and from the answers I received from various people in reply to my questions, the proportion was nearer 50-50 than the figure I gave recently.

MR. PATERSON:—When I got back from the war, we had 2000 horses; we began replacing them with motor trucks at the rate of one truck to about four horses. We bought over 300 motor trucks to replace the horses, in that ratio; but, today, we have 2000 horses.

To summarize, we place the following services at the disposal of our patrons:

Express Delivery.—We make express delivery of goods and parcels throughout Greater London. We will if desired, collect the value of goods on delivery. Our drivers are supplied with cards for distribution to patrons; when a card is displayed by a patron, the driver will call at the patron's house.

Forwarding.—Patrons can hand our drivers packages to be forwarded to any railroad station or port at home or abroad. If so instructed, our drivers will obtain railroad tickets for patrons. We pack goods for export, make out bills of lading and effect clearances through customs offices

Distribution.—In London, we receive goods consigned in bulk to railroad terminals, wharves or highway transportation, split the bulk and distribute the parcels to their various destinations

Direct Delivery.—We supply motor trucks or horse-drawn trucks to customers who have goods warranting the use of a special truck in shipping from one address to another. We do not undertake household removals

Motor Vehicles.—We arrange to supply motor trucks, lettered with our customer's name, to be used entirely by the customer in his own business; also, we supply broughams for use by travelers

Horse-Drawn Trucks.—We also supply horse-drawn trucks, painted as the customer desires, and to be at his sole disposal

Public Garages.—We own motor-vehicle garages in the City, in the West Central District and in several other London Boroughs. These are open day and night for use by the public. Gasoline, tires and all accessories are sold, and the maintenance of customer's motor vehicles is undertaken. At certain garages, all types of storage-battery can be charged

Truck Maintenance.—We build motor-vehicle bodies and horse-drawn trucks. We make contracts for their maintenance and painting; also for lamps, harness and advertising signboards

Building Repairs.—We have a building staff that is prepared to quote prices for erecting new buildings or for making repairs to old buildings, whether for private or for business use

Warehousing.—We arrange to care for baggage, private effects and merchandise but do not handle furniture

Insurance.—We are prepared to arrange for any form of insurance in connection with any one of the foregoing businesses

Forage.—We supply forage for horses, of the same quality as that supplied our own horses. Prices for forage are low, because of the volume of our own purchases. Such forage is supplied to our customers in our own sacks

THE NATION'S WEALTH

ACCORDING to the computations of the Bureau of the Census, the total national wealth of the American people at the end of December, 1922, may be estimated at a money value of $320,803,862,000, an amount which compares with the Bureau's estimate of $186,299,664,000 as representing our national wealth at the end of 1912. On the face of these figures, the money value of the wealth of the Country increased by $134,504,198,000, or 72.2 per cent, during the little more than a decade from 1912 to 1922. This increase in the money value of our national wealth however, as the Bureau is careful to point out, must not be taken as signifying a corresponding proportional increase in our real wealth; during the years from 1912 to 1922, as everybody knows, a remarkable rise of the general level of prices for all kinds of property occurred, and this must be taken into account in estimating the increment of our real wealth. The Census Bureau has not undertaken to determine how large the per cental increase of our real wealth was during the period stated, but it is self-evident that it was far less than 72.2 per cent.—*Economic World.*

ADOLPH E. BRION

ANNOUNCEMENT is made by Peter A. Frasse & Co., Inc., New York City, of the death on Jan. 25, 1925, of Adolph E. Brion, president of the corporation, in the 61st year of his age and the 47th year of his association with this firm. He was born on March 19, 1863, at Brooklyn, N. Y., and received his education in the public schools there. His practical experience was wholly in the steel, steel tubing and supply business, and he invented and patented several mechanical devices during his career. He has been an Associate Member of the Society since 1912.

Principles of Steam-Cooling Systems

By N. S. Diamant[1]

Annual Meeting Paper *Illustrated with* Drawings

ABSTRACT

Quick warming up, a uniform operating-temperature and slow cooling-down after stopping the engine are the objects sought and accomplished in the application of so-called steam-cooling methods to internal-combustion engines, according to the author, who asserts that engineers and manufacturers are wasting valuable time and energy on conventional methods of cooling that have some decided disadvantages instead of investigating and adopting other cooling methods that appear to present simple remedies for the cooling difficulties. He deplores the retardation of development along this line because of the involved patent situation and asserts the belief that research in this field is much more important than patents and patentees and that the latter, while entitled to fair compensation, should have enough sportsman's spirit to go ahead with their work, expecting not only such compensation but also some academic credit.

In an attempt to dispel the confusion that apparently exists regarding the underlying principles involved and the ways in which they are applied, the steam or evaporative system is described as a method of cooling in which the engine is water-jacketed in the usual way, water or a water-alcohol solution covers the cylinder-heads and surrounds the exhaust-valves at all times and is circulated thermodynamically or by a pump, heat rejected to the jackets raises the temperature to the boiling point and thereafter vaporizes the liquid at a temperature dependent on the pressure on the free surface of the liquid, the temperature of the liquid is maintained at a definite point and no special provision is made for cooling it except that the vapor is condensed and returned to the jackets.

The author illustrates and describes the layout or disposition of the jackets, steam-chest or dome, radiator or condenser and pump or other means for returning the liquid to the jackets and maintaining the pressure under which the several systems operate. In some the steam-chest is directly above and integral with the water-jacket, and the condenser is above the steam-chest so that the vapor rises, is condensed and returned directly to the steam-chest. In others the condenser is located in front of the engine in the usual position of the radiator of an automobile. In either system a pump inserted in external piping at a point below the bottom of the water-jacket maintains pressure in the system. In other systems the steam-chest is in front of the engine and the condenser either above it or forward of it. These various dispositions of the elements of the several systems are summarized briefly for convenience.

Heat transference from the jacket walls to the liquid is more rapid in those systems in which the rate of circulation of the liquid is more rapid. Size of pipe connections used makes little difference in operation, except that pressure in the steam-chest may be a little higher with pipes of small internal diameter.

Most of the systems described will, if designed intelligently and incorporated in the vehicles intelligently, result in as satisfactory performance of the engines in present-day cars, trucks and tractors as when they are water-cooled in the usual way, the author states.

Considerable confusion seems to exist in the minds of advocates of steam, radio-condenser or evaporative systems of engine cooling, as well as in the minds of its opponents, regarding the underlying physical principles involved. At least, the application of the physical principles, as stated by both sides, is not always strictly correct. Such confusion or misapplication has interfered with elucidation of the facts and the adoption or rejection of the system.

The automotive engineering profession and the industry are either shortsighted or retrogressive, because they are not investigating and adopting a thing of merit or are wasting time and energy on something impractical and worthless. These statements will not appear unduly exaggerated when we consider that, although the conventional systems of cooling have some very decided disadvantages, comparatively little time and talent are being devoted to systematic research in the field of cooling problems. The steam system appears to present a very good simple remedy, and other systems can be developed which offer technically sound and commercially practical solutions. One at least has been developed.

In this paper I shall confine myself to an analysis of the constructional details of steam systems as applied primarily to road vehicles so that we can understand easily and classify intelligently the various systems that have been patented or proposed.

The steam or evaporative system of cooling may be defined, for the purposes of this paper, as a means of cooling in which the parts of the engine to be cooled are water-jacketed in the usual way but no special provision is made for appreciably cooling the water, so that the water in the jackets is allowed to reach its boiling point, after which the heat rejected to the jackets vaporizes the liquid at a temperature which depends on the pressure exerted on its free surface. Vapor or steam given off at the free surface is led into a condenser or radiator, which condenses it and returns it to the jackets. The condenser is normally empty. Later I shall refer briefly to systems that include a radiator in series with the jackets.

Engine Fevers and Chills Avoided

Most of the systems operate at about 212 deg. fahr., or at an atmospheric pressure of 14.7 lb. per sq. in. As the pressure varies with altitude and other conditions, the boiling point of course will also vary. If desired, a steam-cooling system can be operated at more than atmospheric pressure and at a correspondingly higher temperature, although there seems to be little necessity or desire, at the present time, to use temperatures above 212 deg. fahr. For those who wish to adopt lower temperatures,

[1] A.S.A.E.—Consulting engineer, National Radiator & Mfg. Co., Detroit.

such as from 170 to 190 deg. fahr., ordinary alcohol-water solutions afford a very simple and reliable means. There should be no objection to the use of alcohol in both winter and summer since, with a properly operating steam system, there is no loss of alcohol by evaporation as is the case with conventional systems.

Table 1 gives average values of the temperature of the jacket-water which are met with in practice, where no thermostats or shutter devices are used.

TABLE 1—AVERAGE VALUES OF JACKET-WATER TEMPERATURES

Engine Outlet Temperature, Deg. Fahr.	Engine Inlet Temperature, Deg. Fahr.	Circulation
	Summer	
170 to 200	7 to 20 deg. below those for outlet	Pump
195 to 205	40 to 80 deg. below those for outlet	Thermosiphon
	Winter	
100 to 150	7 to 20 deg. below those for outlet	Pump
180 to 200	50 to 130 deg. below those for outlet	Thermosiphon

These are merely average values and neglect entirely the fact that a few high-priced and most low-priced cars and trucks and the majority of tractors are not well

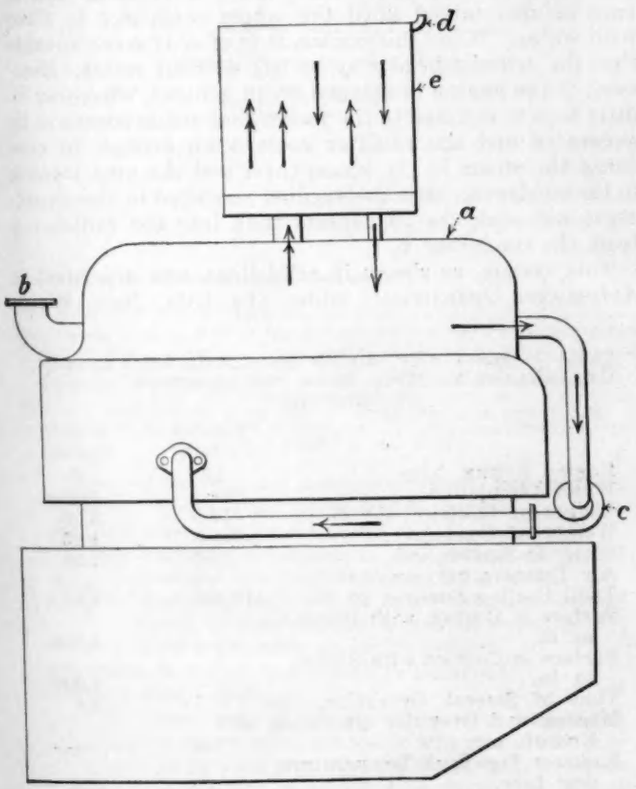


FIG. 1—SYSTEM IN WHICH THE WATER-JACKETS MERGE INTO THE STEAM-CHEST

The Steam-Chest *a* Is Partially Filled with Water to the Level of Filler *b*. When the Engine Is First Started the Parts Above the Water-Level Are Filled with Air, as Vent *d* at the Top of Radiator *e* Is Open, and the System Operates at Atmospheric Pressure. When the Water Has Come to the Boiling Point, Steam Will Be Given Off and Force the Air Out of the Radiator, Be Condensed and Will Return to the Steam-Chest and Jackets, as Shown by Arrows. Water Circulation Is Provided by External Piping from the Water-Level to the Bottom of the Jackets and by a Pump, *c*, Below the Jackets

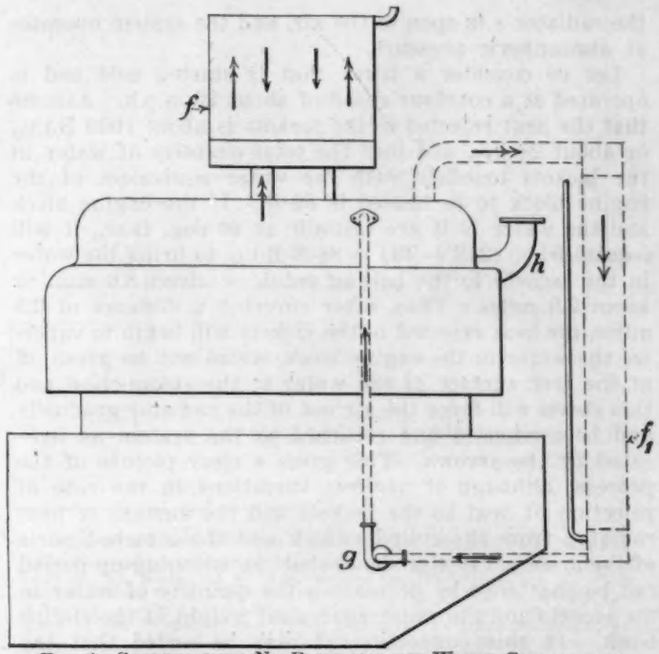


FIG. 2—SYSTEM WITH NO PROVISION FOR WATER CIRCULATION

This Depends for Circulation on Natural Convection and the Ebullition Due to Boiling. An Alternative Form Is Shown in Dotted Lines. In One Arrangement the Radiator *f* Is Above the Engine and in the Other the Radiator f_1 Is in Front of the Engine and a Pump, *g*, Lifts the Condensate from the Bottom of the Radiator to the Steam-Chest

cooled but the water boils considerably even in fairly level terrain, to say nothing of mountainous sections, and in the Western and Southern States. Notwithstanding this, the conclusion to be drawn from the figures must be that the average engine is, within a large range of temperature, quite immune to the diseases of "fever" or "chill" to which the human machine seems so addicted, or perhaps that the public is paying rather dearly for the chronic "colds" and "fevers" of the automobile engine.

No attempt will be made in this paper to deal with the interesting and important subject of the effect of high jacket-water temperatures of the order of 212 deg. fahr. on the mechanical, thermal and volumetric efficiency of the engine and, consequently, on its reliability, flexibility and performance. However, I may state that if it be considered preferable to operate an engine at all times with the water-jacket temperature at 170 or 180 deg. fahr. irrespective of speed, load and air temperature, a radio-condenser system using a suitable alcohol-water solution should prove useful and desirable.

MAIN ELEMENTS AND THEIR DISPOSITION

The main elements of an internal-combustion-engine cooling system are:

(1) The jacket
(2) The steam-dome or steam-chest
(3) The radiator or condenser
(4) The means for maintaining the pressure under which the system operates

Practically all the forms which have been tried or proposed so far have been obtained by arranging these four elements in various ways.

Fig. 1 shows a system in which the water-jackets merge into the steam-chest *a*. This chest is partially filled with water to a level determined by the location of the filler *b* with respect to the steam-chest. When the engine is first started, the parts of the system above the water-level are full of air, since the vent *d* at the top of

the radiator e is open to the air, and the system operates at atmospheric pressure.

Let us consider a truck that is started cold and is operated at a constant speed of about 20 m.p.h. Assume that the heat rejected to the jackets is about 1000 B.t.u., or about 28 hp., and that the total quantity of water in the jackets together with the water equivalent of the engine block to be heated is 50 lb. If the engine block and the water in it are initially at 40 deg. fahr., it will require $50 \times (212 - 40) = 8600$ B.t.u. to bring the water in the jackets to the boiling point, or about 8.6 min. or about 2.9 miles. Thus, after covering a distance of 2.9 miles, the heat rejected to the jackets will begin to vaporize the water in the engine block, steam will be given off at the free surface of the water in the steam-chest and this steam will force the air out of the radiator gradually and be condensed and returned to the system as indicated by the arrows. This gives a clear picture of the process, although it neglects variations in the rate of rejection of heat to the jackets and the amount of heat radiated from the cylinder-block and the attached parts of the system. It also shows that the warming-up period can be shortened by decreasing the quantity of water in the jackets and the water-equivalent weight of the engine block. In this connection, it may be added that the specific heat of iron is about 0.10 to 0.12 for engine-block temperature, so that, while 1 B.t.u. will raise the temperature of 1 lb. of water 1 deg., 1 B.t.u. will raise the temperature of about 10 lb. of iron 1 deg.

The arrangement shown in Fig. 2 is like that in Fig. 1 except that the external part of the jacket circuit connecting its upper and lower portions has been eliminated, and thus no water circulation is provided other than the local circulation within the jackets due to natural convection and the ebullition of boiling.

Two alternative forms of radiator are shown. In one, the radiator f is above the engine as in Fig. 1; in the other indicated by dotted lines, the radiator f_1 is in front of the engine and a pump g lifts the condensate from the bottom of the radiator to the steam-chest.

In Fig. 3 the location of the radiator with relation to the engine is again such that it becomes necessary to use a pump j to lift the condensate from the bottom of the radiator to the jackets. In this case the condensate is fed to the jackets at a point below the water-level and a check-valve k or some equivalent means is added to prevent the water in the jackets from flowing back into the radiator core l. It is immaterial what mechanical or other means is adopted to lift the condensate from the radiator bottom-tank to the jackets so long as it is dependable and drains the tank well enough under all conditions so as not to form a water seal to the vent and interfere with its action. The suction of the manifold can be used, if desired, or a venturi tube can be inserted in the pipe-line m and the suction at the throat of the venturi made to lift the water.

Operation with Steam-Chest Below Jackets

A form is shown in Fig. 4 that is considerably different from the preceding ones. In this the steam-chest is below the jackets, which arrangement gives it novelty but necessitates making provision to maintain the free surface from which steam is given off, at a level below the radiator core n. This has been accomplished in practice by S. W. Rushmore by a positive gear-pump o. When the pump is not running, the water stands at the level p, filling the reservoir q and also part of the radiator. With the conventional relative positions of radiator and engine, the upper parts of the water-jacket and cylinder-head are left dry. As soon as the gear-pump is started, it should pump water from the reservoir into the jackets and, after filling these, should maintain a circulation in the jackets and should also maintain the water-level at r, just below the bottom of the radiator core, at all speeds. When the water in the radiator bottom-tank begins to give off steam, the steam rises into the condenser, is condensed and then returned to the system.

System with Radiator in Series with Jackets

Fig. 5 shows a disposition of elements in some steam-cooling systems in which the radiator u is included in series with the jackets. It is clear that if this radiator be large enough, the system will operate as an ordinary pump or thermosiphon system, as the case may be, but, if the radiator is made sufficiently small or proves sufficiently small at any time, the circulating water will begin to boil and give off steam. Two alternative condenser arrangements are shown. When the condenser v is disposed as shown in dotted lines, the steam rises, forces the air in the condenser out through the vent w and is condensed and returns to the jackets by gravity. In the second arrangement, shown in solid lines, the steam must build up sufficient pressure to be forced down the pipe into the condenser v_1 against its natural tendency to rise. It is then condensed and drops down, the water filling the tank x at the bottom of the condenser. This process will continue as long as the engine is running and it may be maintained until the whole condenser is filled with water. When this occurs, it is of course conceivable that the cylinder-head may be left without water. However, if the engine is stopped or, in general, whenever so little heat is rejected to the jacket that steam ceases to be generated and the radiator cools down enough to condense the steam in the steam-chest and the pipe leading to the condenser, then the vacuum produced in the steam-chest will suck the condensate back into the radiator u from the condenser v_1.

This system, as shown in solid lines, was described in *Automotive Industries*[1], under the title, New Water Steam Cooling System. The information presented in Table 2 was given, based on ground tests made on a Curtiss C-6 Mountain Oriole airplane.

TABLE 2—RESULTS OF GROUND TESTS MADE ON A CURTISS C-6 AIRPLANE EQUIPPED WITH TWO DIFFERENT COOLING SYSTEMS

	Original System	Steam System
Engine Rating, b.hp.	135	135
Water Circulation	Pump	Pump
Weight of Radiator, lb.	58.0	57.6
Weight of Condenser, lb.	——	1.25
Water in System, gal.	7.50	7.50
Air Temperature, deg. fahr.	41	38
Total Cooling Surface, sq. in.	19,600	8,000
Surface in Contact with Water, sq. in.	——	4,000
Surface in Contact with Steam, sq. in.	——	4,000
Time of Smooth Operation, min.	1.5	2.8
Missing and Irregular Operation at End of, min.	6.5	——
Radiator Top-Tank Temperature, deg. fahr.	215	220
Temperature of Water Returned to Block, deg. fahr	——	187
Speed of Engine at Start, r.p.m.	1,450	1,450
Speed of engine at End, r.p.m.	1,300	1,450

A little study will show that there are a number of

[1] See *Automotive Industries*, Sept. 20, 1923, p. 581.

discrepancies and the test results are not so convincing as they may appear at first. If, with the steam system, a radiator having 4000 or even 8000 sq. in. of cooling surface was sufficient to cool the water from 220 to 187 deg. fahr., it is difficult to see why a radiator having 19,600 sq. in. of cooling surface did so poorly, even allowing for lesser cooling efficiency and lower mean water-temperature. It is unfortunate that the area of the cooling surface of the condenser was not given and also the temperature of the water returned to the engine when it was tested with the original system.

Summary of Various Steam-Cooling Forms

Summarizing the various arrangements described and their operation, the facts can be put in more convenient form as follows:

(1) Jackets.
- (*a*) Upper and lower portions connected externally by a pipe and circulation maintained by a pump or by natural ebullitional currents
- (*b*) Upper and lower portions of jackets not connected externally and no circulation except natural convectional local circulation from the hotter to the cooler parts of the jackets

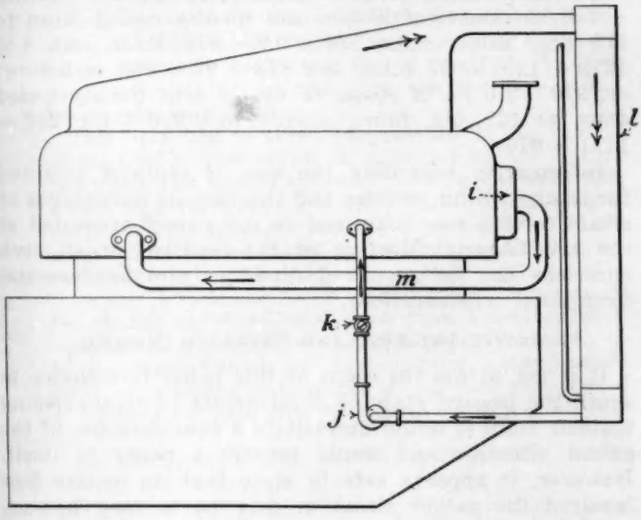


Fig. 3—System with Radiator in Front and Pump Circulation
The Condensate Is Fed to the Jackets at a Point Below the Water-Level by Pump *j* and a Check-Valve, *k*, Prevents Water from the Jackets Flowing Back into Radiator Core *l*. Suction of the Manifold Can Be Used Instead of a Pump To Lift the Condensate or a Venturi Tube Can Be Inserted in the Pipe-Line *m*. Any Means May Be Adopted So Long As It Is Dependable and Drains the Bottom-Tank Well Enough to Prevent the Condensate from Forming a Water Seal to the Vent

(2) Radiator Location
- (*a*) Radiator or condenser above steam-chest and condensate returned to system by gravity
- (*b*) Radiator bottom-tank below steam-chest and a pump or some suction means employed to lift and return condensate to the system

(3) Place to Which Condensate Is Returned
- (*a*) Steam-chest
- (*b*) Lower part of jackets. If radiator core is not above water-level, the water will rise in the core and to prevent this a pump, check-valve or other suitable means is provided

(4) Steam-Chest Location
- (*a*) Above jackets
- (*b*) Below jackets

(5) Steam-Chest Pressure
- (*a*) Atmospheric
- (*b*) Higher than atmospheric. This may result from such a disposition of the elements of the system that pressure is required to force the steam downwardly against atmospheric pressure, or from the small size of the steam pipes or from sharp bends, etc. It may be secured also by use of a pressure valve that will prevent escape of air from the radiator when a predetermined pressure is reached, but in this case means must be provided to admit air and relieve the partial

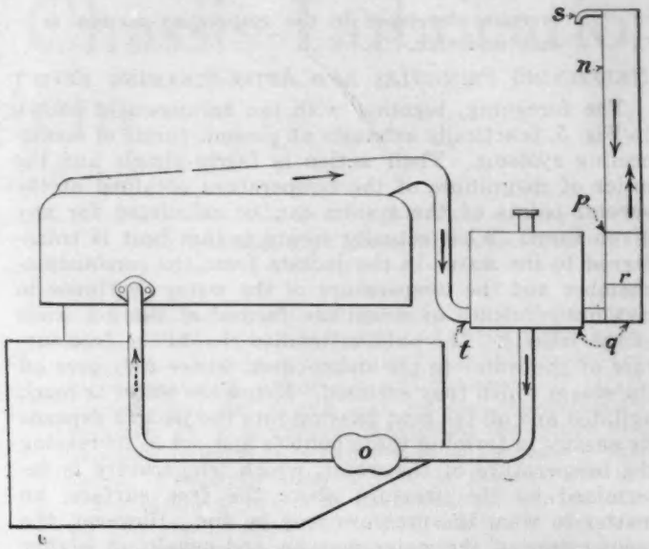


Fig. 4—System Having Steam-Chest Below the Jackets
This Necessitates Making Provision for Maintaining the Free Surface of the Water at a Level Below the Radiator-Core *n*. This Is Accomplished by a Positive Gear-Pump, *o*. When the Pump Is Not Running, the Water Stands at the Level *p*, Filling Reservoir *q* and Part of the Radiator, the Upper Parts of the Cylinder-Heads Being Left Dry. As Soon As the Pump Is Started, It Should Pump Water from the Reservoir into the Jackets and When These Are Full Should Maintain Circulation in Them and Also Maintain Water-Level *r* Just Below the Bottom of the Radiator-Core at All Speeds. When the Water in the Radiator Bottom-Tank Begins To Give-Off Steam, the Steam Rises into the Condenser, Is Condensed and Then Returned to the System

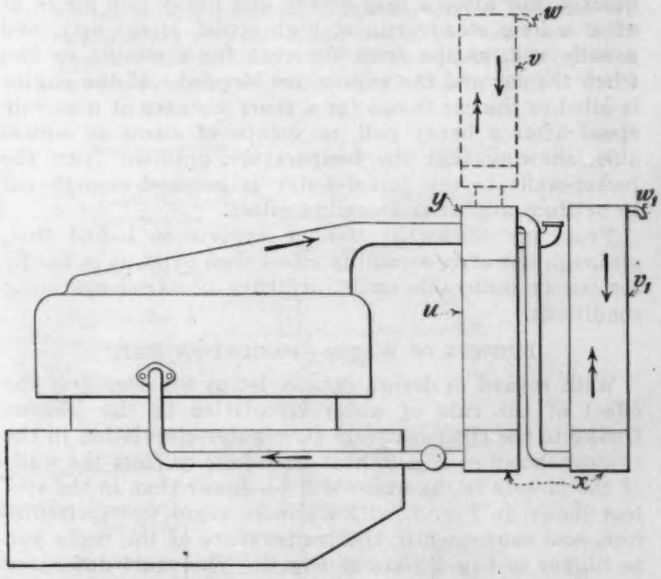


Fig. 5—System with Radiator in Series with Jackets
This Will Operate as an Ordinary Pump or Thermosiphon System if the Radiator Is Large Enough, but If It Is Sufficiently Small the Water Will Begin To Boil and Give-Off Steam. With the Condenser Located as Shown in Dotted Lines, Steam Forces the Air in the Condenser *v* Out through Vent *w* and Is Condensed and Returns to the Jackets by Gravity. In the Alternative Arrangement Shown in Solid Lines, the Steam Must Build Up Sufficient Pressure to Be Forced Down the Pipe into the Condenser v_1, where It Is Condensed, the Water Filling the Tank *x*. This Continues So Long as the Engine Is Running, but When the Engine Is Stopped or Steam Ceases To Be Generated and Radiator *u* Cools Down Enough To Condense the Steam in the Steam-Chest, the Vacuum Produced in the Steam-Chest Will Suck the Condensate Back into Radiator *u* from Condenser v_1

vacuum developed in the system, as vacuum is not desirable.

Underlying Principles and After-Steaming Effect

The foregoing, together with the arrangement shown in Fig. 5, practically exhausts all present forms of steam-cooling systems. Their action is fairly simple and the order of magnitude of the temperature obtained at the several points of the system can be calculated for any given form. What actually occurs is that heat is transferred to the water in the jackets from the combustion-chamber and the temperature of the water continues to rise until bubbles of steam are formed at the hot walls of the jackets. The bubbles tend to rise to the free surface of the water in the steam-chest, where they give off the steam which they enclosed. Hence the water is much agitated and all the heat passing into the jackets expends its energy in forming these bubbles and not in increasing the temperature of the water, which temperature is determined by the pressure above the free surface, no matter to what the pressure may be due. However, the temperature of the water may be, and usually is, higher than that of the steam or vapor and in any case there is a dropping temperature-gradient from the hot jacket-walls to the free surface at which vaporization occurs. Thus, when a car is stopped quickly and the engine is also stopped, so that the condensing effect of the radiator is reduced practically to nil, the generation of steam in the steam-chest does not cease but continues for from 1 to 3 min. until the temperature of the inside jacket-walls and that of the water in the jackets is equalized. This also occurs, of course, with present conventional systems but it does not make itself apparent unless the water is at the boiling point. With steam-cooling systems that are properly designed and cooled, I have observed that, under ordinary conditions, no after-steaming effect is noticeable when the car and the engine are stopped quickly, but after a long steady and heavy pull uphill or after a long steady run at high speed, steam may, and usually will, escape from the vent for a minute or two when the car and the engine are stopped. If the engine is idled or the car is run for a short distance at moderate speed after a heavy pull, no escape of steam is noticeable, showing that the temperature gradient from the jacket-walls to the jacket-water is reduced enough not to produce any after-steaming effect.

From my somewhat meager experience I find that, although the after-steaming effect does exist, it is hardly serious or noticeable under ordinary practical operating conditions.

Effects of Water-Circulation Rate

With regard to design details, let us consider first the effect of the rate of water circulation in the jackets. Owing to the comparatively slow water circulation in the system shown in Fig. 2, heat transference from the walls of the jackets to the water will be slower than in the system shown in Fig. 1, with its more rapid water circulation, and consequently the temperature of the walls will be higher in Fig. 2 than in Fig. 1. The exact difference in jacket-wall temperature between these two will depend on the total resistance to heat transference in the two cases. The total resistance consists of (*a*) the comparatively low resistance of the metal, (*b*) the resistance of the water, which is a function of the velocity of the water, and (*c*) the resistance of the scale formation on the jacket-walls.

Such design details as the size of pipe-connections to be used for leading steam to the condenser and for returning the condensate to the system require little comment, as they can be derived from a study of the system under consideration and from the specifications to be met. I have used steam pipes as small as 5/16-in. inside diameter and as large as 1¾-in. inside diameter. With most systems it makes little difference what size is used except that the pressure in the steam-chest is a little higher in the former case.

For the condensate I have used pipes from 5/16-in. inside diameter up to ¾ in. Roughly speaking, every 1000 B.t.u. rejected to the jacket will produce about 1 lb. of condensate, since the latent heat of vaporization is about 970 B.t.u. If, however, the steam coming from the steam-chest is wet and contains, for example, 50 per cent of water vapor, the same 1000 B.t.u. rejected to the jacket will produce 2 lb. of condensate instead of 1 lb., and similarly for other qualities of steam. It will be seen in this connection that the effect of cooling down the condensate to 212 deg. fahr. or 50 to 100 deg. below that temperature, will be comparatively small. For example: 970 B.t.u. = 1 lb. of steam of 100-per cent quality = 1 lb. of steam of 90-per cent quality cooled down to 115 deg. fahr., since $970 \times 0.9 = 873$ B.t.u. and $1 \times (212 - 115) = 97$ B.t.u. and $873 + 97 = 970$ as before; or, 970 = 1.5 lb. of steam of 60-per cent quality cooled down to 147 deg. fahr., since $0.60 \times 970 + 1.5\ (212 - 147) = 970$.

Information regarding the size of radiator required for steam-cooling systems and the various advantages of steam cooling was contained in my paper[3] presented at the 1924 Annual Meeting of the Society; or all such questions can be answered directly from fundamental theoretical considerations.

Active Interest and Research Needed

It is not within the scope of this paper to examine in detail the present state of development of steam-cooling systems since it would necessitate a consideration of the patent situation and would require a paper in itself. However, it appears safe to state that no matter how involved the patent situation may be or may become, what is needed at present is interest in the subject; active and intelligent interest that will bring about a preliminary but thorough and systematic study of the subject of engine cooling in general and steam cooling in particular. I believe that research is much more important than patents and patentees. The patentees, I believe, deserve credit for the work they have done, as a matter of elementary justice; they are also entitled to just compensation on a royalty or some other basis for any novel ideas their inventions may embody, provided these ideas have merit. The real inventor should, and will, have sufficient sportman's spirit to go ahead with his work expecting fair compensation for his patentable ideas and an academic sort of credit for the rest of his contributions.

Most of the systems I have described will work when applied to present-day cars, trucks or tractors if they are intelligently designed and intelligently incorporated in the vehicles. When I say they will work, I mean that the engine will perform apparently as well on the road when steam cooled as it did when water cooled. As to whether this proves that steam cooling is practical I do not care to commit myself, but it looks hopeful, and I believe that those who undertake some real research along these lines will be more than compensated even for the experimental outlay, besides receiving other tangible and intangible benefits.

[3] See The Journal, April, 1924, p. 396.

The Central-Point Chassis-Lubrication System

By JOSEPH BIJUR[1]

DETROIT SECTION PAPER *Illustrated with* DRAWINGS AND PHOTOGRAPHS

ABSTRACT

DISAGREEABLE jobs are put off by most persons as long as conscience will permit or the necessities of the case will allow. Oiling of the chassis of an automobile is probably the most unpleasant task in connection with keeping a car in good running condition, because it usually involves a preliminary washing of the car and is at best a dirty job and one that often requires the contortions of a gymnast. These facts account in a large measure for the many squeaky cars and the poor condition of wearing parts of used cars offered for sale. If the whole chassis could be lubricated as easily as the engine, as by pouring oil into a single receptacle and letting the car itself do the rest, most motorists would feel that the automobile millenium was approaching.

This condition is closely approached in the central lubricating system which is described by the author and which has been in successful use for a considerable period on several cars that have been lubricated by it while covering mileages ranging from 15,000 to 25,000 miles. The author states that these cars did not develop squeaks nor show any appreciable wear.

In this system the 50 or more lubrication points on the chassis are supplied with oil from a central lubricator or oil reservoir on the dash under the hood. A hand-operated pump or gun supplies approximately 50 lb. of pressure to force the oil through all parts of a copper-tube pipe line to control outlets located at the points requiring an oil supply. Normally the system is solidly full of oil and the oil is not under pressure but whenever it is desired to oil the chassis the pump handle is pulled out and released. It is retracted by a coil spring that supplies the necessary pressure, which is uniform throughout the system and causes a uniform rate of oil flow to all bearing surfaces. Ordinarily about 1 min. is required for the pump piston to return to its normal position and for all points to be oiled, but in cold weather it may take 10 times as long, owing to the greater viscosity of the oil.

Control outlets called drip-plugs are located at the oiling points to regulate the quantity of oil discharged. The rate of flow through these is regulated, for bearings needing large or small quantities of oil, by the tolerance between annular channels in the drip-plugs and pins inserted in the channels. The rate of flow of ordinary oil at room temperature ranges from 3 drops per min. with a 0.061-in. pin in a 0.063-in. hole to 30 drops per min. with a 0.056-in. pin in a hole of the same size.

Pipe lines are concealed and protected within the chassis frame and behind the splash aprons, wheels and springs. Oil is conveyed from the lines on the frame to unsprung parts on the axles through piping formed into helical bridges that absorb the stresses due to flexure of the springs. The oil line can be disconnected at any point or a portion can be removed for replacement with but slight loss of oil since there is no pressure on the oil. Air that may be introduced as a consequence of such replacement or as a result of the

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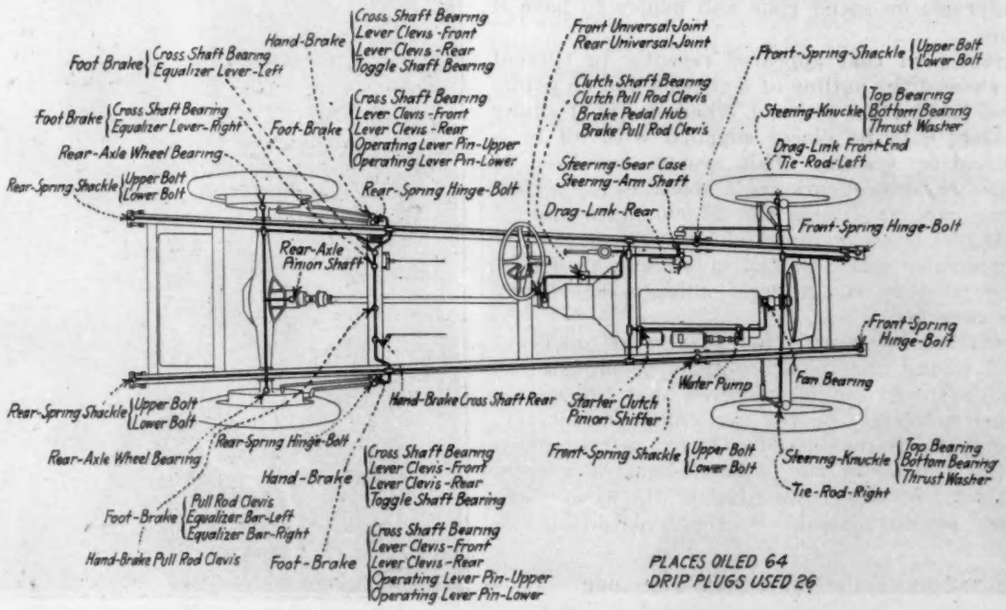

FIG. 1—PLAN OF CHASSIS SHOWING 64 PLACES OILED BY THE CENTRAL SYSTEM
Heavy Black Lines Represent Copper Tubing $\frac{1}{4}$ In. in Diameter Which Is Normally Full of Oil from a Reservoir on the Dash. The Oil Is Not under Pressure Until a Pump Handle in Front of the Driver Is Pulled Out and Released, When a Uniform Pressure of 50 Lb., Imposed by a Compression Coil-Spring in the Pump, Forces Oil to Control Outlets, Indicated by Lines Drawn to the Legends

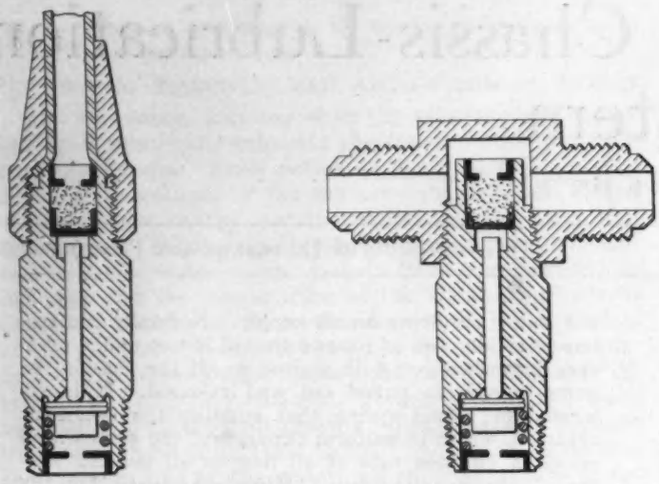

FIG. 2—DRIP-PLUGS OR CONTROL OUTLETS

The One at the Left Is Used at the End of an Oil Line and the One at the Right at an Intermediate Point in the Line, Like an Electric Light Bulb in a Single-Wire Electrical System. Oil Passes From the Line Pipe Through an Axial Hole 0.063 In. in Diameter in the Plug in Which Is Fitted a Steel Pin from 0.002 to 0.007 In. Smaller in Diameter Than the Hole. Below the Pin Is a Metal Relief-Valve Faced With Soft Material That Is Impervious to Oil. The Valve Is Held against Its Seat by a Phosphor-Bronze Spring and Prevents Leakage When the System Is Not under Pressure

lubricator tank becoming empty, is quickly eliminated through vents in the lubricator or through the drip-plugs.

Cars designed for use of the system require very little piping, and mechanical front-wheel brakes, together with the wheel bearings and all attached steering mechanism, are readily oiled through internal channels.

ENTIRELY apart from the engineering principles and details discussed herein, an oiling system whereby all parts of an automobile chassis requiring lubrication are supplied simultaneously with oil from a central point by pressure has a human interest in its appeal to the car-owner, who now either has to do a more or less dirty and irksome job of lubricating at frequent intervals or spend time and money to have it done for him.

An advertisement that appeared recently in current periodicals showed the outline of a chassis and 58 points that required lubrication by hand, whereas Fig. 1 shows another chassis with 64 places supplied with oil by a central lubricating system. This system has been in successful use on several cars for a considerable period. Two of these cars have been run 25,000 miles and all have gone 15,000 miles or more, all without squeaks or showing appreciable wear; in fact, a well-designed self-oiled chassis must be run a great mileage before any wear can be detected.

The illustrations presented herewith were taken to make the oil piping and its connections prominent but the impression should not be gathered that the apparatus is rather noticeable on the car. On the contrary, it is so inconspicuous that a self-oiled car is recognized chiefly by the absence of the usual oil-cups or grease-gun connections. Moreover, all parts of the system are well protected against damage by rough usage or collision.

SYSTEM NORMALLY NOT UNDER PRESSURE

Referring to Fig. 1, copper tubing of 3/16-in. diameter is used throughout for the pipe line, which is kept full of oil. Normally the oil is not under pressure, but when the lubricator is operated the oil in the entire line is subjected to a pressure somewhat in excess of 50 lb. and the control outlets emit predetermined quantities of oil during the pressure period, which lasts for about 1 min. Distribution of the oil is controlled without the use of mechanism or moving parts, hence the equipment requires no attention whatever except for replenishing the oil supply at intervals of 2 months or more.

To understand this distribution, assume for a moment that the line is solidly full, with all outlets tightly sealed. If the line is connected to a source of pressure, the oil will be at a uniform pressure throughout, since no flow occurs. Now if each outlet is opened the smallest conceivable amount, so that oil oozes out very slowly, a very slow movement of oil through the piping will take place. This condition is not very different from that in which the openings were closed and the pressure conditions throughout the line will not be greatly different. There will, however, be a small variation in pressure from point to point, caused by pressure being used up in producing the flow. It will be understood readily that the pressure losses will be small if this rate of flow is kept down, so that the pressure at the more remote points will not differ greatly from the pressure at the source of supply. The outlets emit oil so slowly that the pressure variation in the line is well within 10 per cent of the average pressure, which, for the purposes of distribution, may be considered as substantially uniform pressure throughout.

DRIP-PLUGS CONTROL OIL FLOW

The construction of a control outlet, known as a drip-plug, is shown at the left in Fig. 2. This fitting is threaded at its lower end directly into a bearing, the

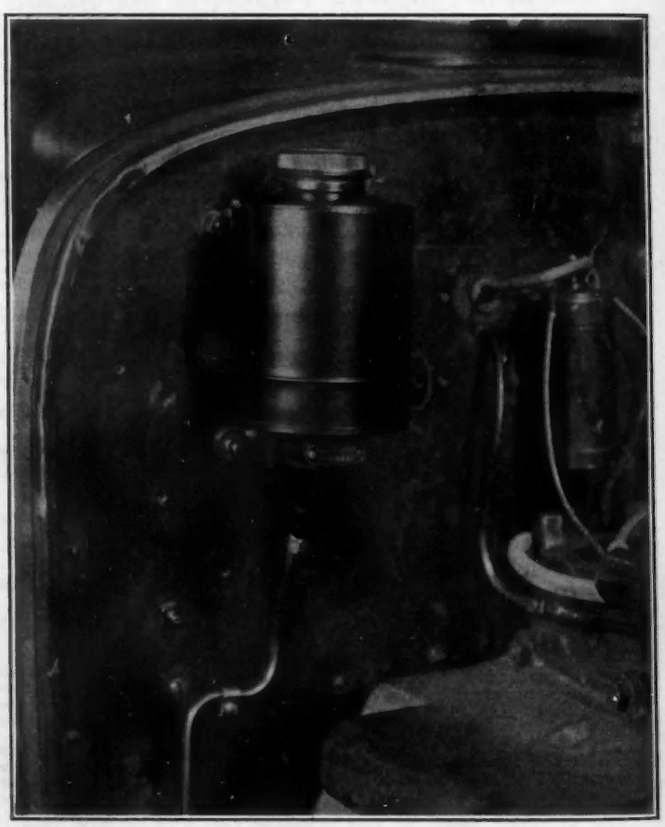

FIG. 3—CENTRAL LUBRICATOR OR OIL RESERVOIR

This Is Mounted on the Dash under the Engine Hood with Its Single Outlet Connected to the Chassis Lubrication Oil Line. A Spring-Actuated Pump, Supported by a Stamped Bracket, Passes Through the Dash to the Base of the Lubricator

upper threaded part receiving a flared pipe-connection. Emission of oil is restricted by an accurate hole 1/16 in. in diameter and ½ in. long in which is placed a pin of nearly equal size but leaving a minute annular orifice that presents a high resistance to flow. Below this pin is a metal relief-valve faced with a soft material that is impervious to oil and is pressed against an annual valve-seat by a phosphor-bronze spring. A metal-to-metal valve that could be relied on to be tight when normally closed and yet open under light oil-pressure, would entail very expensive manufacture and even then would be likely to leak if the smallest particle of dirt lodged on the valve-seat. The soft facing overcomes these difficulties and, with the tight valves made possible by this construction, no oil leaks from the outlets, no oil drips on the garage floor, and the pipe line is always solidly full of oil from the central lubricator to each outlet.

It is evident, however, that foreign particles should be prevented from lodging in a valve and that accumulation of dirt in a restriction would change its flow-resistance. To avoid this, a felt-strainer plug supported by a gauze

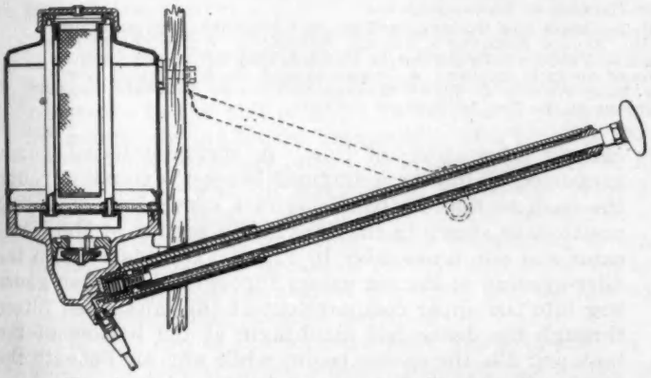

FIG. 4—ASSEMBLY OF LUBRICATOR AND PUMP, IN SECTION

Oil Introduced at the Top of the Lubricator Is Strained through a Fine-Mesh Gauze Bag, Filling the Tank Proper, and Then Filters through a Dense Felt Diaphragm into the Spaces Below, Any Air Therein Escaping through Two Vent Tubes. The Pump Plunger Is Held in Its Normal Indicated Position by a Long Coil Compression-Spring. When the Handle Is Pulled Out, About a Tablespoonful of Oil Is Drawn through the Valve at the Base of the Lubricator and through Two Small Holes into the Base of the Pump Cylinder. When the Handle Is Released the Spring Forces the Piston Down Slowly and the Back-Pressure Closes the Valve and Forces the Oil Out through the Outlet Below the Pump End into the Chassis Oil Line. When the Piston Reaches the End of Its Stroke, It Seals Both the Inlet and Outlet

cup is mounted in the inlet of the fitting. This strains out of the oil any small particles of dirt without itself offering any considerable resistance to slow flow, but it should not be called upon to filter large quantities of dirty oil, as there would be a likelihood of covering its surface with sufficient dirt to form an obstruction. To avoid this the entering oil is finely filtered in the central lubricator, leaving the strainers in the drip-plugs to intercept only the dirt that might come from the inside of new pipe or from threaded parts. The total quantity of such dirt does not begin to clog them nor increase their flow-resistance measurably. A pressure of about 12 lb. per sq. in. is required to open a valve and, while the pressure lost in passing through the strainer varies with the flow, it is of such a low order that it may be taken as averaging 3 lb. per sq. in. Thus, with a line pressure of 55 lb. per sq. in., 15 lb. is absorbed in the strainer and valve, leaving 40 lb. effective to force the oil through the restriction.

RATE OF OIL-FLOW

With this pressure and using ordinary engine oil at room temperature, different rates of flow result from using pins of various diameters in the control outlets, as

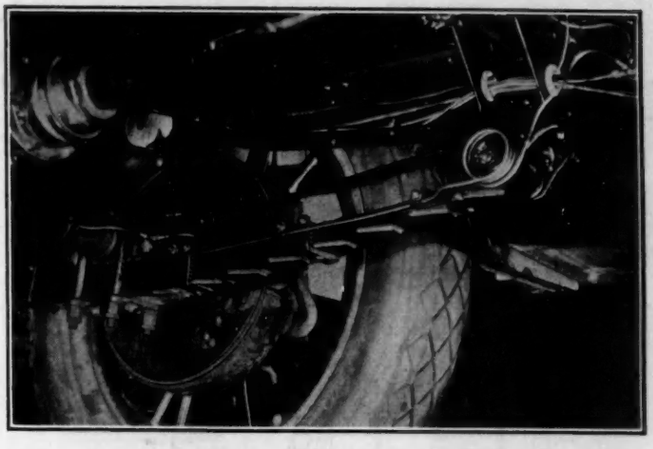

FIG. 5—METHOD OF CONVEYING OIL FROM PIPING ON MAIN FRAME TO REAR-AXLE PARTS

A Section of Hard Seamless Brass Tubing Is Connected to the Main Line on the Frame, Wound into a Helix at the Spring Hinge and Continued along the Side of the Main Leaf of the Spring, to Which It Is Clamped. The Helix Absorbs the Bending Stresses Due to Flexure of the Spring without Fatigue of the Metal of the Tube. The Helical Portion Is Protected by a Housing That Was Removed for the Taking of the Photograph

shown in Table 1 in which 1 cc. (0.061 cu. in.) is taken as equivalent to 20 drops of oil, although this relation is only approximate.

TABLE 1—CONTROL-OUTLET SIZES AND RATE OF OIL-FLOW

Hole Diameter, In.	Pin Diameter, In.	Rate of Oil-Flow Cc. per Min.	Approximate Drops per Min.
0.063	0.061	0.15	3
0.063	0.060	0.25	5
0.063	0.059	0.40	8
0.063	0.058	0.63	12
0.063	0.057	1.00	20
0.063	0.056	1.50	30

Resistance to oil-flow in any chassis bearing, whether tight or loose, is obviously many times less than that of a drip-plug restriction and also, if a piping system is laid out with fair regard to even distribution, its resistance is so low compared with that of its drip-plugs that the pressure losses in it may be disregarded. Therefore the drip-plug is a means of controlling oil-flow that is substantially independent of the tightness of the bear-

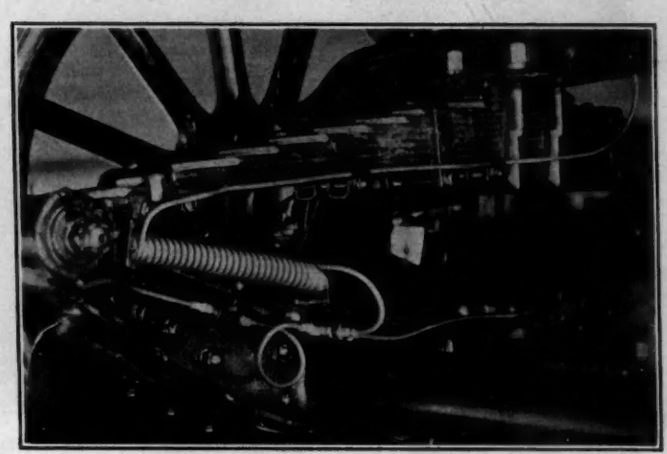

FIG. 6—TRANSFER OF OIL TO FRONT-AXLE PARTS BY A SPRING BRIDGE

The Tubing Is Wound into a Long Coil That Is Screwed at Either End over Studs on the Frame and Top Leaf of the Spring. Thence the Tube Is Carried along the Top Leaf to a Point above the Axle, Then Down to the Rear of the Axle and Outward to the Steering-Knuckles at Either End

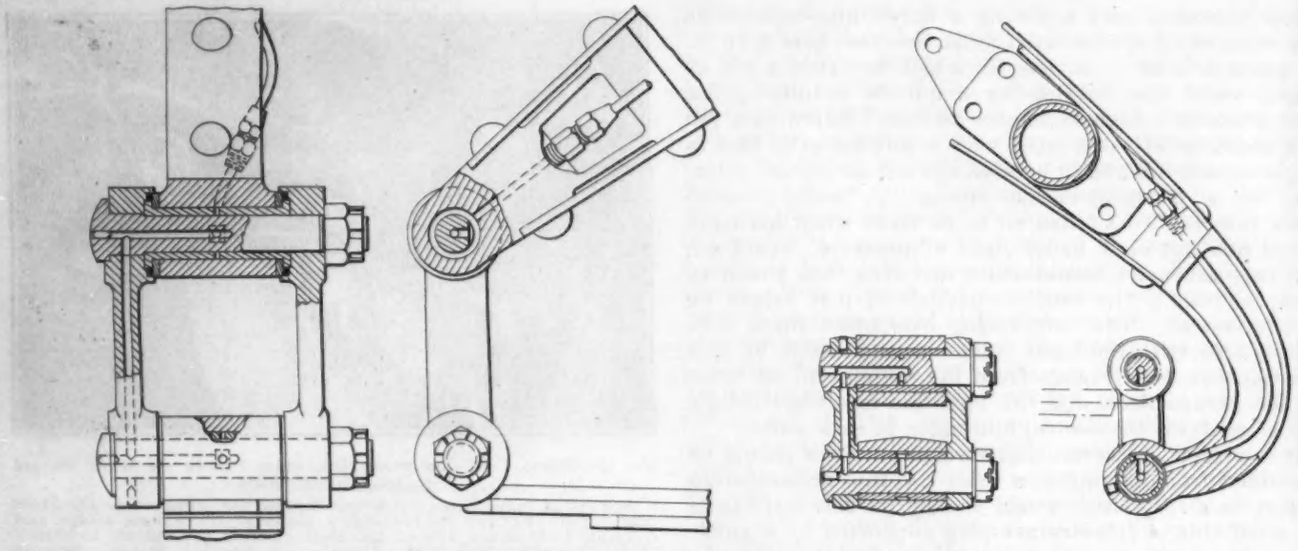

FIG. 8—CONSTRUCTION OF DIRT-EXCLUDING SPRING-SHACKLE

Lateral Travel of Dirt Is Prevented by Overlapping Parts of Bolts, Links and Bushings and by Felt Ring-Washers, as Shown at the Left. The Two Bolts Are Identical and Interchangeable. At the Right Is a Tension Shackle in Which Oil Is Fed to the Top Bolt without the Use of Flexible Connections or Extra Parts. A Drip-Plug Is Formed Directly in the Link by Drilling a Long Hole and Inserting a Pin a Few Thousandths of an Inch Smaller. A Groove around the Lower-Bolt Bushing Conveys Oil to the Top or Loaded Surface of the Lower Bolt, Whence It Flows through Continuous Oil-Tight Ducts to the Upper Bolt, Which Has a Groove at the Top for Exit of the Oil

ing to which it is applied or of the location of the bearing on the car.

The drip-plug shown at the left in Fig. 2 is used as the terminal of a line, as at the ends of the frame, but when it is desired to carry the line past the point to be oiled, a drip-plug in the form shown at the right in Fig. 2 is used. In this the flow-controlling elements are in the stem of the T and oil flows freely through the head of the T to the line beyond. Such T drip-plugs are mounted on spring-shackles and in various accessories on an engine that are lubricated readily from a single line using this type of plug.

CONSTRUCTION OF LUBRICATOR AND PUMP

Fig. 3 shows the lubricator, mounted on the engine side of the dash, with its single outlet connected to the chassis lubrication oil line. A spring-actuated pump, supported rigidly by a stamped bracket, extends through the dash so that its handle is in a convenient operating position, as shown in the drawing in section of the lubricator and pump assembly in Fig. 4. Oil poured into the filler-opening at the top passes through a fine-mesh gauze bag into the upper compartment of the tank, then filters through the dense felt diaphragm at the bottom of the tank and fills the spaces below, while any air beneath the felt escapes through two vent tubes.

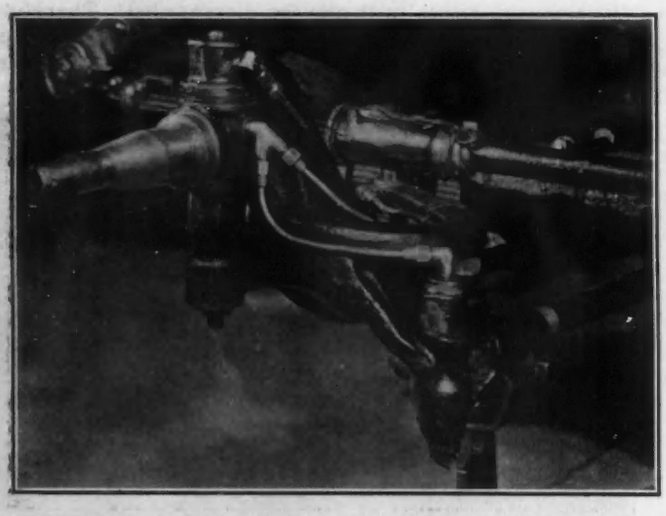

FIG. 7—METHOD OF OIL DISTRIBUTION TO KNUCKLE AND STEERING CONNECTIONS WITHOUT USE OF SWIVELS

The Oil Pipes Are Short, Protected and Concealed by the Wheel When It Is in Place. Oil Is Conveyed from the Ball Stud on the Wheel Knuckle to the Ball Stud on the Steering-Gear Lever through the Drag-Link. All Ordinary Assemblies and Adjustments Can Be Carried On without Regard to the Oiling System and the Mere Assembling of the Parts Forms the Proper Oil Ducts

A pair of drilled holes, shown in dotted lines, communicate between the valve-chamber and the pump or gun cylinder, and when the piston is pulled out its full stroke about a tablespoonful of filtered oil is drawn from the chamber into the gun cylinder. Upon releasing the handle, the spring pushes the piston down and the backward flow of oil around the inlet-valve closes the valve. As the chassis oil line is solidly full of oil, the oil pressure instantly rises to its full value and persists throughout the stroke. A spring of great free length and under strong initial-compression is used, hence the oil pressure remains constant throughout the stroke within 10 per cent of its mean value. At the lower end of the piston is a self-aligning extension which seats tightly at the end of the stroke on a leather washer, sealing the inlet from the tank to the gun and also the outlet from the gun to the line.

The piston will ordinarily descend in about 1 min. During this time a small amount of oil might leak up past the leather piston-cups and eventually accumulate above them but to avoid this four holes are drilled in the gun cylinder just above the upper end of the stroke to furnish a drain for such oil into a sleeve surrounding the lower part of the cylinder and thence to the engine side of the dash.

HOW AIR IS ELIMINATED FROM THE SYSTEM

It is obvious that high and uniform line-pressure contributes to uniform predetermined distribution and makes negligible any small commercial variations in the valve-opening pressure of the drip-plugs. Such line pressure, which is attained readily when the line is solidly

filled with incompressible oil, is affected unfavorably by appreciable quantities of air in the line; therefore the apparatus is arranged to avoid the introduction of air, even when the tank is empty. In this condition there is no longer enough oil to close the inlet-valve; consequently no pressure can be developed and, as the inlet-valve remains open all the while, the piston can merely draw up a charge of air from the valve chamber and return it promptly thereto, without forcing either oil or air into the line. Incidentally, the rapid descent of the handle gives the driver notice that the lubricator tank needs filling.

When the gun is used to fill an empty line, the first stroke of the piston discharges oil into the line and, as the bore of the line is so small that air and oil will not pass each other, the air beyond the oil is compressed slightly. There would be a tendency for the gun to suck part of this oil back out of the line the next time the handle is pulled were it not for a loosely-fitting ball-check valve in the gun outlet which serves only to impede such return flow and plays no role in the normal operation of the system.

As more and more oil enters the line, the air beyond is compressed into the ends of the line whence it readily escapes through the various drip-plugs, which offer little resistance to the exit of air. Therefore, to remove the air completely and fill the lines solidly with oil when they and the lubricator are empty, it is only necessary to fill the lubricator with oil and operate the handle 10 or 15 times. From this it will be seen that if a section of pipe is replaced at any time, thus introducing a long bubble of air, a few strokes of the gun will cause this air to escape through the nearest drip-plugs and the line will resume its normal oil-filled condition.

The line can be disconnected from any drip-plug, or a section of pipe replaced, without material loss of oil, because the gun piston seals the inlet to the line at the end of its stroke and the relief valves in the drip-plugs prevent reverse flow through them, so that air cannot enter the line at any point and it is plain that oil will not run out anywhere if the line is opened.

It may be pertinent to remark, since this lubricating system uses oil, that oil appears to be the best lubricant for chassis wearing-surfaces when it is applied at sufficiently short intervals. Grease squeezes out from the wearing surfaces under load and does not flow back, whereas an oil-film, if broken, is at once restored and creeps by capillarity to whatever parts are in wearing contact.

Like Single-Wire Electrical System

An analogy exists between the system here described and the single-wire system of electrical energy distribution. The high-resistance drip-plugs correspond to the high-resistance incandescent lamps and the low-resistance pipe line corresponds to the low-resistance copper wire. A lamp can be placed in the electric circuit at any desired point merely by running an appropriate wire from the main lead to the lamp and thence to a ground. Similarly with the oil system, a drip-plug can be located anywhere on the chassis and merely connected to the nearest oil-lead with the shortest convenient pipe. The constant pressure of the oil system while the piston is descending is analogous to the constant voltage of the electric system, and the function of the gun as a generator of oil pressure is like that of the generator which generates and maintains the electrical pressure. The only considerable difference in the analogy between the two systems is that the high-resistance filaments in the lamps operate at such a high temperature that their life is limited, whereas the drip-plugs, not being subjected to any destructive effects, do not wear out in use.

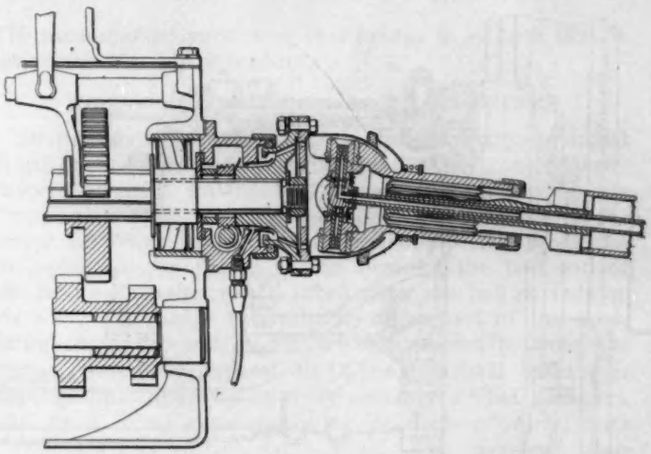

Fig. 9—A Method of Oiling Both Universal-Joints

Oil Is Admitted through the Drip-Plug at the Lower Rear of the Transmission Box into a Stationary Annular Lip, Whence It Drips Into an Annular Trough That Revolves with the Joint. When the Joint Stops Revolving in the Position Shown, a Small Quantity of Oil Runs by Gravity through an Internal Tubular Connection to the Rear Universal-Joint

This analogy may help to show to those who are familiar with voltage drop in electrical circuits that the distribution of oil is not affected by temperature so long as the oil remains fluid, and as to this, oil that remains fluid at a temperature as low as — 20 deg. fahr. may be had for especially cold climates. Although the viscosity of lubricating oil varies enormously with temperature and may be 10 times greater in cold weather than on a hot day, the distribution of the oil nevertheless always remains the same, because the resistances of the various parts of the system bear a fixed relation to one another. Regardless of temperature, the operator pulls out the

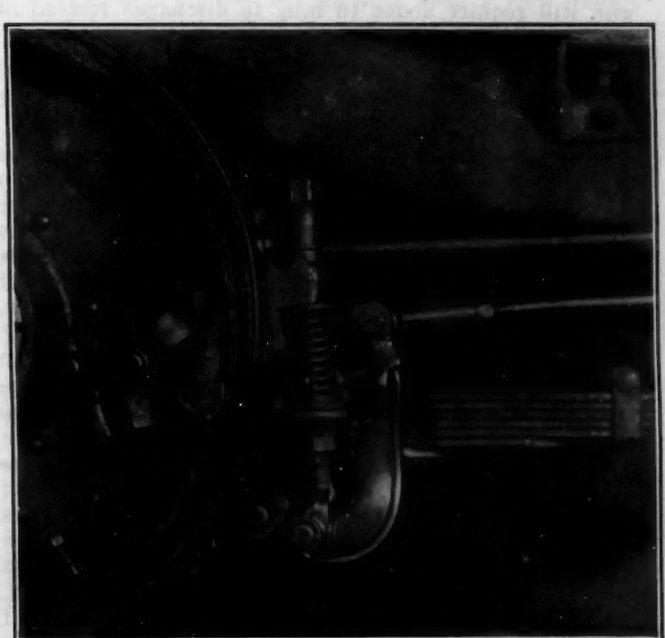

Fig. 10—Single-Source Lubrication of Brake Linkage

The Brake-Operating Lever Is Fed from an Adjacent Bearing and Oil Flows through the Hollow Pull-Rod and Is Led from the Lower End through the Pipe on the Brake-Band Lever to the Two Lower Brake-Band-Lever Pins. Joints in the Rods and Levers Are Adjustable To Take Up Side-Shake, and Overlapping Flanges Exclude Dust

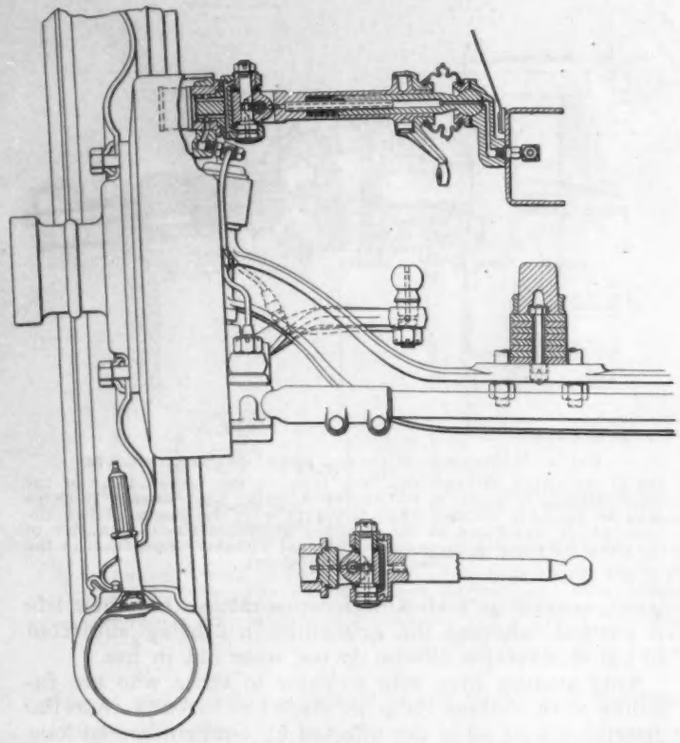

FIG. 11—DISTRIBUTION IN MECHANICAL FRONT-BRAKE AND STEERING CONNECTIONS

Oil Is Fed from a Drip-Plug on the Side Frame, at the Upper Right, through the Ball End of the Brake-Operating Shaft, Lubricating the Ball Joint and the Telescopic Joint between the Two Parts of the Shaft. Drilled Passages Lead It into and through the Universal Joint to the Camshaft Bearing within the Brake Drum. This Bearing Drains Into a Collecting Pocket, Whence the Oil Is Distributed to the Ball Studs on the Steering-Rod and Tie-Rod Arms. An Oil Supply Having Been Brought to the Top of Each Steering Knuckle, It Can Be Distributed to All Adjacent Bearings Without an Oil Line on the Front Axle

handle with the usual ease, but in very cold weather the gun will require about 10 min. to discharge instead of the customary 1 min.

How Oil Is Carried from Frame to Axles

Several methods to carry oil from the line on the frame to the axles with unquestioned reliability have been developed. One method is to use a length of hard seamless brass tubing that extends continuously from a junction on the frame to another on the rear axle by way of the spring, as in Fig. 5. A part of the tube is wound into a helix that is co-axial with the hinge-bolt of the vehicle spring, while the rest of the tube extends alongside of the main leaf, to which it is attached by a few clamps. These clamps fasten to the main leaf so securely that they cannot be dislodged and they hold the spring run of the tube in a protected position where it takes the same distributed flexure as the spring leaf. The helical portion is carried in a protective housing not shown in the photograph and accommodates itself readily to the hinging motion. The whole arrangement is such that the stresses anywhere in the tube never approach its elastic-limit. Those who have followed experiments on fatigue of metals may recall that no fatigue limit has been found for metals of this kind when thus stressed. We have tested such spring-runs for 1,000,000 cycles of alternate deflection through their full range, far beyond what they receive during the life of a car, without any resultant damage.

Another type of "bridge," carried in a protected position and concealed by the splash apron, is used at the forward end of the frame, where the large-diameter helix shown would be in an exposed position. The appearance of this "bridge," with the splash apron removed, is shown in Fig. 6. A close-wound coil is screwed at its upper end over a threaded stud carried by the frame and the lower end is carried by a similar stud clamped to the top spring-leaf near its hinging point.

Distribution to Steering-Mechanism Bearings and Spring-Shackles

Given a reliable method of leading oil under pressure to the front axle, the distribution of oil on the axle is simple, as shown by Fig. 7, in which the steering-knuckle and its associated bearings are oiled without the use of swivels. The oil pipes are short, well protected and not easily seen unless the wheel is removed, as when the photograph was taken. Oil may be carried from the ball stud on the wheel-knuckle back to the ball stud on the steering-gear lever through the drag-link, which can be arranged not only to have a small oil storage but to be a self-contained assembly capable of being mounted and dismounted as a unit regardless of the oiling system. Similarly, the ball stud in the steering-gear is removable without regard to the presence of oil ducts, and the steering lever is also removable, a diagonal hole conveying the oil to it without weakening the shaft. In fact, all ordinary assemblies and adjustments can be carried on as usual without regard to the oiling system. Furthermore, the mere assembling of the parts forms the proper oil ducts.

If working parts of a car designed with fair regard to low unit-pressures are well lubricated, dirt, acting as an abrasive, becomes the principal cause of wear. A simple means of excluding dirt from a shackle is shown in Fig. 8, at the left. Whereas a conventional shackle has four open cracks in which dust can lodge, the parts here overlap and concealed felt rings are provided to prevent lateral travel of dirt. The bolts can be assembled in only one position in the hollow link and both bolts are alike; no rights or lefts or top and bottom have to be considered, so a general interchangeability is maintained throughout these constructions. A corresponding construction is used in the spring hinge.

Feeding oil to the top bolt of a tension shackle without the use of flexible connections or extra parts possesses a point of interest. A shackle of this type, of conventional construction except for the lubrication, is shown at the right in Fig. 8. The long drilled hole in the link is filled with a pin a few thousandths of an inch smaller than the hole so that the entire annular space between the pin and the hole is constantly full of oil, held there by capillary attraction. The bolts are press-fitted in the links, so that a continuous oil-tight passage from the inlet in the lower bolt to the outlet of the upper bolt is provided. A groove around the lower bushing conveys oil to the top or loaded surface of the lower bolt, and thence it flows through a passage in the bolts and link to the upper bolt, and since this oil is transmitted across the loaded surfaces wear will not cause any appreciable leakage. The upper bolt has a groove at the top to permit free exit of oil and, inasmuch as the bolts are different, they are made of different sizes to prevent incorrect assembly. The oil pipe lies inside of the groove in the forging, where it cannot be damaged by a tow rope.

Oiling Universal-Joints and Brake Linkage

One method of oiling both of the universal-joints is shown in Fig. 9. Whenever the front joint stops rotating in the position shown, a small quantity of oil runs by

gravity through an internal tubular connection to the rear joint. Oil is supplied to the first joint by a drip-plug feeding the inside of a stationary annular lip, which in this case is pressed into the speedometer-drive gear-housing, whence it drips into an annular trough that revolves with the joint.

Bearings of the brake linkage can be lubricated from a single source, in the way shown in Fig. 10. A stud is pressed into the lower end of the brake-operating lever, which is fed from the adjacent bearing, and oil from the stud flows through the hollow pull-rod and feeds a similar stud pressed into its lower end. A pipe brazed on the brake-band lever conveys oil to the two lower pins. The joints are adjustable to take up side-shake, overlapping flanges exclude dust and the oil has a general tendency to wash dirt away, thus leaving the passages unobstructed.

When a car is designed originally to take this system, only a little piping is required to distribute oil to 45 lubrication points. Oil flows to the rear axle through a torque-arm line which is connected to the pipe line on the side-member by a bridge of seamless tubing. A drip-plug lubricates the ball joint at the front end of the torque-arm and also its hinged support. A hollow spring-bridge is composed of two short helical coils of hard brass tubing, threaded over suitable studs, and the various motions of the front end of the torque-arm are accommodated chiefly by axial deflection of the two coils. The unsupported portion of this bridge is so light that it cannot be set into vibration.

Ingenious Lubrication of Front Brakes

Drip-plugs toward the front of the car feed mechanical front brakes and parts associated with them, incidentally dispensing with the need of a separate oil line to the front axle. Fig. 11 shows the construction by which the oiling of front brakes is accomplished. Oil from the drip-plug on the frame passes through the ball end of the brake-operating shaft, lubricating the ball surface on its way, and thence through the other half of the operating shaft, lubricating the telescopic joint between the two. Thence the path of oil to the camshaft bearing is through the universal-joint by suitably drilled passages, the joint being constructed to be dirt-excluding, with horizontal and vertical bolts alike. The camshaft bearing drains into a collecting pocket, whence the oil is finally distributed to the ball studs of the steering-rod and tie-rod arms. It is almost impossible for oil to reach the braking surfaces but, even if it did, minute quantities of such oil would have no effect on braking action.

Once the oil supply is brought to the upper part of each knuckle, it can then be distributed to all of the adjacent bearings, which are really part of the knuckle, so that an oil line on the front axle is not needed. This use of the brake-operating shaft as an oil bridge does not greatly alter the conventional construction.

THE BUSINESS OUTLOOK

THE real progress made by agriculture is to be measured by debt reduction, by the tendency toward desirable diversification and better methods and by the gradual drift from country to city, which is tending to bring domestic production nearer to domestic consumption. By these tests the gains made have been modest and the probability exists that better prices will defer further progress.

Next to agriculture in importance in connection with the business outlook in the United States are building and construction and railroad expenditures. Although in some localities and in some kinds of building the shortage that so long existed may have been made up to a considerable extent, the normal increase in population always must be provided for, an increase now estimated at somewhat less than 1,500,000 persons each year. Last year was a record year for building and construction. It is probable that activity in 1925 will show considerable irregularity between different localities and classes of construction, but it seems certain that the total will be large.

All will agree that in the long run the United States will profit from a resumption of normal economic life in Europe. Demand for raw materials, such as cotton and copper, is now increasing, and the demand for American food products may increase to some extent. However, if the Dawes Plan is to succeed, Germany must pay reparations by the export of manufactured goods. If other countries of Europe are to enjoy genuine prosperity, they, too, must expand their exports of manufactures. The economic existence of Western Europe depends on an increase in these exports.

France, Italy and some other European countries are of rapidly increasing industrial importance. The leading countries of the non-European world all are struggling for industrial self-sufficiency. Europe has skill, and competition between the recovering European nations is fairly certain to bring labor costs there even below present levels.

The United States must reckon on growing European competition. It is already evident in some lines that tariff walls are a very imperfect protection in the domestic market. Every practical manufacturer knows that United States production costs are now so high as to make it very difficult to export profitably except in lines possessing natural advantages such as cheap raw materials, advantages growing out of patent rights or low costs due to the enormous domestic market and large-scale production. No appearance of impending prosperity should blind American business to these facts.

Our price level is already high compared with many other countries. Advancing prices and their certain corollary, advancing wages, could quickly make it impossible for American manufacturers to meet the European products in markets open to both, and foreign manufacturers would increasingly find themselves able to scale any tariff wall.

Higher prices for finished manufactures would raise farmers' costs. American farmers would be thrust back into the impossible situation out of which they have been struggling, for agriculturally speaking the United States is a high-cost country in most lines, just as it is in manufacturing, and it therefore is not the maker of the world price. The position of some other American producers of raw materials does not differ from that of the farmers. The consequence of rising prices would be diminished exports, increased imports, lessened domestic consumption and business recession. It has long been the expectation in well-informed European quarters that this would be the course of events in the United States. It is yet too early to be certain that these gloomy prophecies by our rivals will not be realized.

If we are to have long-continued prosperity instead of an unsatisfactory spurt in business, we must fit ourselves to meet the stiffest competition in our history. Profits will be made by the discarding of business luxuries and the maintenance of quality, rather than by advancing prices or their equivalent, a lowering of quality.—J. S. Alexander, chairman of the board of directors, National Bank of Commerce in New York.

A Car Manufacturer's Experiences with Balloon Tires

By E. A. De Waters[1]

Annual Meeting Paper

ABSTRACT

In the summer of 1922 the Buick Company began experimenting with balloon tires. The first tires tested, being four-ply and 32 x 6.20 in. in size, produced a galloping action that was sufficient to prejudice the company's engineers against them, and the tests were discontinued. In addition to the galloping effect, other difficulties encountered included those usually present in steering, the development of wheel shimmying to a serious degree, the lack of proper clearance for external brakes because of the small 20-in. wheels, the excessively rapid wear of the tire tread, and the greater susceptibility to puncture. Leaks because of the pinching of the inner tubes also occurred.

When, later, a set of 5.25-in. tires was tried on a smaller car, the galloping was noticeably less; but punctures were more numerous than was the case with high-pressure tires. In another set of 32 x 6.20-in. tires, but of six instead of four plies, galloping was still present, but the durability of the tires was increased. Low resistance to skidding was apparent because of the configuration of the tread, which was of the circumferential-rib variety. It was obvious that defects in the tires must be eliminated before satisfactory results could be expected.

A decision was reached to adopt sizes of balloon tires that would meet the observed conditions and to make the sizes approximately those of the high-pressure tires previously used. After seven test-cars had been driven a total of 1,500,000 casing-miles, these sizes were made standard.

As an excessive number of punctures in four-ply tires was found to result from the pinching of the inner tubes in ruts, when the roads were frozen, it was decided that the rear wheels, because of the greater load carried and the absorption of driving strains, demanded a heavier casing. Increasing the number of plies from four to five in the 31 x 4.95-in. size of tire practically doubled the mileage performance, as did also increasing the number from four to six in the 32 x 5.77-in. size. A remaining trouble, namely, excessive tread-wear on the outer edges of the front-wheel tires, was remedied by raising the air-pressure about 10 per cent.

The conclusions reached are: (*a*) that large-section balloon tires increase the resistance to steering, particularly at the curb, increase the tendency toward shimmying at the higher speeds, set-up a disagreeable galloping action, and increase the liability to blowouts because of the pinching of the inner tubes by deep hard ruts; (*b*) making a compromise by reducing the cross-section of the tire and raising the air-pressure will eliminate the tendency to gallop; (*c*) four plies are sufficient to protect the front wheels against punctures and blowouts; (*d*) more than four plies are needed on the rear wheels because of the greater wheel-loads carried and the absorption of driving strains; and (*e*) from the standpoint of durability, tire pressures should be maintained at the figures recommended.

THIS paper is simply what the title states, a record of experience. It is not to be looked upon as a technical treatise of the subject in any way. Like those of many other engineering organizations, our engineering staff has conducted extensive and comprehensive road-tests of balloon tires. No doubt you have encountered the same difficulties and problems that we have. Our experience will probably check with yours in many respects and possibly our conclusions may be in agreement.

Our first experiments with low-pressure or balloon tires were begun in the summer of 1922, soon after the summer meeting of the society at which the engineering phases of the subject were originally discussed. The first tires tested were of the 32 x 6.20-in. size, the casing being four-ply. The principal problem that presented itself in our first road-tests was the so-called galloping action of the car, a phenomenon that was decidedly objectionable from the riding-quality standpoint. This galloping action did not occur at any particular speed but to a considerable degree was dependent upon the character of the road; and at that time we were unable to overcome it. The galloping phenomena, together with some other troubles, were sufficiently serious and persistent to prejudice us against low-pressure tires of that particular size and cross-section so that no further extensive tests were made at that time. The original experimental tires were run over 4000 miles.

Factors Accompanying Low Pressure

The other factors that contributed to our prejudice against the type of balloon tire first submitted for test were notably the familiar steering difficulties, the development of wheel shimmying to a serious degree, the lack of proper clearance for external brakes because of the small 20-in. wheels, the excessively rapid wear of the tire tread and the greater susceptibility to puncture. We also experienced some difficulty from leaks that resulted from pinched inner tubes. In one instance, the test-car had three tube failures of this character between Flint and Detroit, a distance of 60 miles. In each case we found that the inner-tube had been pinched in the casing when the tires were crowded into frozen ruts in the roadway but that no failure of the casing had occurred.

Shortly after our unsatisfactory experience with the tires of 6.20-in. section on our larger car, a set of tires of 5.25-in. section was submitted for test on our smaller car. This set of tires was run from 15,000 to 18,000 miles Although the galloping action was only slightly noticeable in tires of this cross-section, punctures occurred much more frequently than in the conventional 31 x 4-in. high-pressure tires that we had been using on this car. Details of the punctures are given in Table 1. Up to this time our tests of both sizes of tire had shown that a car could not be driven an appreciable distance on a flat tire without practically destroying the inner-tube.

Six Versus Four Plies

About this time another tire-manufacturer submitted a set of 32 x 6.20-in. balloon tires for test, these being six instead of four-ply. We found that the galloping

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TABLE 1—RECORD OF PUNCTURES ON 30 X 5-IN. LOW-PRESSURE TIRES

Number of Punctures	Date	Location of Tire	Reason for Puncture	Mileage since Installation
1	9-28-23	Right Rear	7-Penny Nail	39
1	10- 2-23	Right Rear	Shingle Nail	2,206
1	10- 4-23	Right Rear	8-Penny Nail	3,120
2	10- 8-23	Right Rear	8-Penny Nail	5,391
1	10- 9-23	Right Rear	Two ½-In.Tacks	5,598
1	10-10-23	Left Rear	6-Penny Nail	6,087
1	10-10-23	Left Rear	Spike	6,187
1	10-14-23	Right Rear	Nail	8,054
1	10-17-23	Right Rear	8-Penny Nail	9,203
1	10-20-23	Right Front	Thorn Needle	10,929
1	10-21-23		Finishing Nail	11,417
1	10-22-23	Left Rear	10-Penny Nail	11,586
1	10-23-23	Left Rear	Shingle Nail	11,848
1	10-26-23	Left Front	Shingle Nail	13,592
1	10-28-23	Right Rear	8-Penny Nail	14,656

Recapitulation

Date on which Tires were Installed	9-27-23
Total Mileage	15,128
Total Number of Punctures	16

Tires originally were inflated to 25-lb.-per-sq.-in. air-pressure, but on Oct. 15, the pressure was reduced to 20 lb. per sq. in.

Mileage since that date, 6789.

action was present in the same disagreeable way as in the other tires, but the durability of the six-ply tire was greater. Tread wear was nearly comparable to that of a high-pressure tire and fewer punctures were experienced. This set of tires showed little wear after 15,000 miles of service. One objectionable feature of this particular tire was its low resistance to skidding, attributable to the tread configuration, which was of the well-known circumferential-rib variety.

Our unsatisfactory experience with the first low-pressure tires did not prejudice us against them, however, to such an extent that we could not recognize merit in the principle of low-pressure inflation. We knew that the motoring public seldom inflates tires to the high pressures recommended by the tire manufacturers. We were in favor of low-pressure tires but, at the same time, it was apparent that the defects that we had found in them must be overcome before the tires would be satisfactory in the owner's hands.

Adopting Arbitrary Sizes

After studying the results of our tire tests to that date, we decided to select arbitrarily a size of balloon tire to fit the conditions best as they appeared to us at the time. It seemed logical to keep the new sizes somewhere near those that we had been using and that were giving fairly good satisfaction when inflated to the lower pressures. We believed that this method of procedure would cause less disturbance of the steering layout, tend to reduce the disagreeable galloping action, leave the road and fender clearances about the same as those with high-pressure tires, and eliminate brake interference. Based on this line of reasoning, we ordered sample tires of the following sizes: (*a*) 31 x 4.95-in. cross-section, practically the same as that of the old 4½-in. tire, and (*b*) 32 x 5.77-in. cross-section, practically the same as that of the old 5-in. tire.

In increasing the cross-section without changing the standing heights, we believed that we were increasing considerably the factor of safety above that of the conventional high-pressure tires that we had been using and that in most cases were being run with low air-pressures and very satisfactory life.

Our reasons for selecting these arbitrary sizes were discussed with all the leading tire-companies; and representatives of practically all the companies agreed that the selection seemed to be a logical one. Samples were made and submitted by many different tire-manufacturers; and casings of these sizes were driven a total of 1,500,000 casing-miles before a final decision was reached to adopt the sizes for standard equipment. Seven test-cars were used in this investigation, each car being driven 24 hr. of every day. Each car was given a dead-weight load equivalent to the weight of the particular model with its heaviest body and its full passenger-load.

Tires Still in Experimental State

These 24-hr. road-tests convinced us that the design and the manufacture of balloon tires were still in an experimental state, so far as some of the tire-makers were concerned. Wide differences of performance between competing makes of tire showed that some of the makers still had much to learn about the construction of a satisfactory low-pressure tire. For example, two makes of tire that were tested in the large group of samples made for us would not run 1000 miles before the tread rubber separated or broke away from the side-wall rubber. In both cases the tread had been made too thick and had not been properly tapered at the point where it joined the side-wall.

When these new sizes were first selected, all the sample casings were made of four-ply construction. Road testing-service soon demonstrated that leaks, which apparently resulted from pinched inner-tubes, were causing an excessive number of flat tires. This trouble prevailed particularly when driving over rough frozen rutted roads

TABLE 2—RECORD OF TIRE-MILEAGE TESTS PER PUNCTURE

Size	Ply	Location	Number of Casings Tested	Total Casing-Miles	Total Punctures	Number of Makes Tested	Average Mileage
31x4.95	4	Front	54	370,081	22	5	16,821
31x4.95	4	Rear	42	239,155	36	5	6,643
31x4.95	5	Rear	23	196,463	16	4	12,279
31x5.25	4	Front	15	70,928	10	3	7,093
31x5.25	4	Rear	17	69,119	16	3	4,320
32x5.77	4	Front	66	613,751	39	7	15,737
32x5.77	4	Rear	47	281,320	55	4	5,115
32x5.77	5	Front	14	108,549	6	3	18,092
32x5.77	5	Rear	56	303,594	55	5	5,520
32x5.77	6	Front	12	68,513	3	3	22,838
32x5.77	6	Rear	35	220,668	48	4	4,597
33x6.00	4	Front	2	21,400	0	1	21,400
33x6.00	6	Front	6	20,679	3	1	6,893
33x6.00	5	Rear	11	42,051	7	2	6,007
Total			400	2,626,271	316		8,311

TABLE 3—RECORD OF TIRES, SHOWING BLOWOUTS AND FAILURES OTHER THAN PUNCTURES WITH VARIOUS CROSS-SECTIONS AND NUMBERS OF PLIES

Size	Ply	Location	Number of Casings Tested	Total Casing-Miles	Blowouts, Defects, etc., except Punctures	Makes Tested	Average Miles per Failure
31x4.95	4	Front	54	370,081	10	5	37,008
31x4.95	4	Rear	42	239,155	15	5	15,943
31x4.95	5	Rear	23	196,463	7	4	28,077
31x5.25	4	Front	15	70,928	2	3	35,464
31x5.25	4	Rear	17	69,119	2	3	34,559
32x5.77	4	Front	66	613,751	12	7	51,147
32x5.77	4	Rear	47	281,320	24	4	11,721
32x5.77	5	Front	14	108,549	2	3	54,274
32x5.77	5	Rear	56	303,594	18	5	16,866
32x5.77	6	Front	12	68,513	None	3	68,513
32x5.77	6	Rear	35	220,668	10	4	22,066
33x6.00	4	Front	2	21,400	None	1	21,400
33x6.00	6	Front	6	20,679	None	1	20,679
33x6.00	6	Rear	11	42,051	None	2	42,051
Total			400	2,626,271	102		25,748

in the late winter. A careful study of the cause revealed the fact that the light wall-casings broke down on the inner surface of the side-walls as well as on the treads, chafing the inner tubes so that they blew out and sometimes burst the outer casings also. Some instances occurred in which the inner surface of the casing fractured without blowing out; and inspection of them convinced us that the trouble was caused by so-called stone bruises rather than by the pinching of the casings, such as we had experienced on tires of larger cross-section.

Records of Tests

Careful records that had been kept of the experiences with flat tires during the extensive road-tests of the 31 x 4.95-in. and the 32 x 5.77-in. sizes, and an analysis of the causes of the blowouts and punctures, led us to the conclusion that four-ply construction of the size of cord tire that we had been using, although thoroughly good for the front wheels, could not be adopted satisfactorily for the rear wheels. The greater load on the rear wheels and the absorption of driving strains demanded the use of a casing of heavier construction. Again we consulted with the tire-manufacturers and they all agreed that increasing the number of plies was a logical step. Five and six-ply sample tires of the 31 x 4.95-in. and the 32 x 5.77-in. sizes were made and were used on the test-cars. Tables 2 and 3 show the comparative records of the punctures and the blowouts with tires of different sizes and numbers of plies. Note, for example, that a 31 x 4.95-in. four-ply tire averaged 16,821 miles per puncture on the front wheels, but traveled only 6643 miles per puncture on the rear wheels. When the plies were increased to five, the 31 x 4.95-in. tires averaged 12,279 miles per puncture on the rear wheels, practically doubling the previous performance. Table 3 shows the performance when blowouts and failures other than punctures are considered. Note again the increase in mileage after the number of plies on the rear tires had been increased from four to five or six.

Front Tires Less Susceptible to Puncture

It is interesting to see by clear evidence that the front tires of a car are much less susceptible to punctures and blowouts than are the rear tires. Based on this record of performance, we feel safe in saying that tires of lighter construction can be used on the front wheels than on the rear wheels, with entirely satisfactory results.

Having settled the tire construction for front and rear wheels to our satisfaction, so far as punctures, blowouts, and the like, were concerned, our remaining trouble was excessive tread-wear on the front tires, particularly on the outer edges of the tread. After checking-up wheel alignments and different amounts of toe-in, we found the trouble still remained, and we were told by the tire companies that the air-pressures in the front tires should be increased about 10 per cent. This we proceeded to do, and satisfactory wear resulted. Our experience has shown the great importance of maintaining the tire pressures at the recommended figures, if the greatest mileage from tires of the low-pressure variety is to be secured.

Conclusions

Summarizing, our experience has shown that:

(1) Large-section thin-walled balloon tires increase the resistance to steering, particularly at the curb

(2) Large-section thin-walled balloon tires increase the tendency toward shimmying at the higher speeds

(3) Large-section, thin-walled balloon tires that are inflated to relatively low pressures tend to set-up a galloping action of the car that is distinctly disagreeable

(4) Reducing the cross-section of the tire and raising the air-pressure, so that the resulting casing represents a compromise between the very large thin-walled balloon type and the conventional high-pressure type, will eliminate the tendency to gallop

(5) Large-section, thin-walled tires are likely to have blowouts because of the pinching of the inner tubes, particularly if driven in or over deep hard ruts

(6) When low-pressure tires are used on the front wheels, four plies are sufficient to ensure ample protection against punctures and blowouts

(7) More than four plies are needed for the low-pressure casings used on the rear wheels, otherwise the greater wheel-loads encountered and the absorption of driving strains will break down the side-wall until it chafes the inner-tube or becomes weakened to a point at which it will blowout

(8) It is extremely important, from the standpoint of tread durability, that tire pressures should be maintained at the recommended figures

Vol. XVI March, 1925 No. 3

System for Controlling Motorbus Maintenance

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Automotive Transportation Meeting Paper *Illustrated with* Drawings

ABSTRACT

AUTOMOBILES require maintenance. When the number of automobiles, and particularly motorbuses that are performing continuous and rapid service, is large, the system necessary for recording their needs is voluminous. In this paper is described the system developed by the Fifth Avenue Coach Co.

Fundamental to such a system is a knowledge of the mileage covered by the vehicles during a given period of time. This may be obtained by recording the number of trips made by each vehicle over routes, the accurate measurement of which is known, or by mileage recording instruments, the readings of which are taken by the employes before and after the runs are made.

Four mechanical operating divisions are required to maintain the motorbuses of this company, 100 vehicles being assigned to each. In charge of each division are a foreman and an assistant, who report to the superintendent of rolling-stock, who, in turn, reports to the chief engineer. Each mechanic is a specialist and is responsible for the efficiency of a particular unit. In addition to the four operating divisions, two others are required for periodic overhauls, the annual-overhauling shop and the body-overhauling shop.

Every vehicle and every unit part of the vehicle are numbered. The mileage of the tires is obtained by recording the dates on which the wheels are installed and removed. After the record has been made on the unit change slip, the information is transferred to a vehicle mileage and tire record. The cost of tires per mile has been found to vary from 1.0 to 2.5 cents, which represents an aggregate sum of from $140,000 to $350,000 per year for the entire 400 vehicles.

Maintenance should be linked with depreciation; money that is not spent on maintenance should be placed in a depreciation account. To group the maintenance expense, vehicles are separated according to their ages, that is, all those that are put into service during the first half of the year have one shop order number; those put into service during the last half of the year have another order number. Only vehicles of the same type are grouped into the same classification.

The cost of maintaining particular units of the vehicle is also obtained through change slips, which are the same as those used for the tires. An excessive amount of trouble above the usual amount can generally be attributed to the inefficiency of the driver, poor mechanical maintenance, poor material, or inferior design.

All material is obtained through requisitions signed by the foreman, who notes on them the account to which the material is to be charged. Each garage has at least two gasoline-filling and oiling stations, located at sufficient distances within the entrance so that several motorbuses can enter at one time. While the gasoline, oil and water are being replenished, an inspection is made by the driver with the help of the assistant foreman. The result of the inspection, as well as a report with regard to any trouble that has been experienced during the day, is recorded on report cards. In addition to this inspection, a weekly inspection and report are made of all the major units.

After completing 2000 miles, motorbuses are held in the shop for about 5 hr. to undergo a general overhauling. The night force, in addition to replenishing the gasoline, oil and water, sweeps out, cleans and polishes the motorbus, which must also be washed every few days.

As the cost of gasoline is about 3 cents per mile, the cost per vehicle per year is about $1,050; for 400 vehicles, the annual cost is about $420,000. Disbursements of gasoline are carefully checked and the total amount consumed each day is recorded. A quantity reading is also made before and after delivery of gasoline by the oil company. Readings of the gasoline supplied to each driver are a check on the condition of the engine or the possible carelessness of the driver. By comparing this consumption with the mileage, the average miles per gallon can be ascertained. A consistently good average indicates that the vehicle is in the hands of a competent careful driver and that it is in efficient condition.

Oil consumption varies from 200 to 1000 miles per gal. At an average of 300 miles per gal. and a cost of 50 cents per gal., the cost per engine is $56 per year and, for the fleet of 400 vehicles, it is about $22,400 per year. Only the finest quality available is used.

Records of the cause of all involuntary delays are an index to the parts that give the most trouble and are in need of improvement. Other equipment, such as snow-plows and sand-trucks, the operation of which is infrequent, are inspected often enough to make sure that they are ready for immediate service.

TRANSPORTATION is among the most fundamental of the needs of mankind; the motorbus is an application of the automobile to this common want. The automobile within a decade has revolutionized the Nation's habits. Today, more than 15,000,000 vehicles give power to America, important among them being the motorbus, which is rapidly increasing in number. But automobiles, and particularly motorbuses that are performing such continuous and rapid service, have needs of their own; they require maintenance, and it is the requirements of this maintenance that will be outlined in this paper.

The first fundamental requirement for a system of transportation records is accurate knowledge of the mileage covered by the vehicles over a given period of time. Many ways are known to all of you as to how this information can be acquired. In the case of an established motorbus system, the lengths of the routes may be measured, and the employes may simply record on their daily cards the number of times that a vehicle has traversed a given route; from these cards the mileage may accordingly be obtained.

Another method is the use of some of the well-known instruments for recording mileage, the readings of which are taken by the employes before they begin and after they have finished the work, so that the difference be-

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FIFTH AVENUE COACH COMPANY
PERSONNEL ESTABLISHMENT-OPERATING DEPARTMENTS
COMPARED WITH PAYROLL-WEEK ENDING _____

Description of Work	No. 2 Garage 113th Street 2nd Floor East				No. 3 Garage 102nd Street				No. 4 Garage 132nd Street 2nd Floor West				No. 5 Garage 132nd Street Basement				TOTAL			
Day Force 60 Hr. per Week	Established		Actual		Established		Actual		Established		Actual		Established		Actual		Established		Actual	
	Men	Hr.	Men	Hr.	Men	Hr.	Men	Hr.	Men	Hr.	Men	Hr.	Men	Hr.	Men	Hr.	Men	Hr.	Men	Hr.
Engine Repair Men																				
Body Repair Men																				
Chassis Repair Men																				
Bus Cleaners																				
Floor Cleaners																				
TOTAL																				
Night Force 70 Hr. per Week																				
Bus Attendants																				
Bus Cleaners																				
TOTAL																				
Total General Overhaul																				
Average Hours per Man per Week																				
Total Payroll per Week																				
Cost per Mile																				
Total Mileage per Week																				
Hours Overtime																				
No. of Buses																				

FIG. 1—PERSONNEL RECORD SHEET
On This Sheet Are Recorded Each Week the Number of Men Employed and the Hours of Work. Other Data Such as the Total Weekly Payroll, the Mileage per Week, the Cost per Mile and the Number of Buses Operated Are Also Tabulated

tween the two readings will show the mileage that has been covered in that interval.

In managing a fleet of automobiles, one naturally wishes to keep records of its wants and behavior, because excessive consumption of material and misbehavior in public service will surely bring disaster to the persons interested in making their living or in obtaining profit from the enterprise.

FOUR OPERATING DIVISIONS

In the organization of the Fifth Avenue Coach Co. are comprised at present four mechanical operating divisions, each caring for approximately 100 revenue and non-revenue vehicles. The personnel of these divisions is under the direct supervision of the superintendent of rolling-stock, who reports to the chief engineer.

Under the superintendent of rolling-stock are the general night foreman, and a day as well as a night foreman, with an assistant for each foreman for each division. These foremen cover 24 hr. in shifts as indicated in Table 1.

FIFTH AVENUE COACH COMPANY
Sunday Working List

Week ending _____ 19____

NAME	Occupation	On Sun	Off Mon	Off Tues	Off Wed	Off Thur	Off Fri	Off Sat	REMARKS

Foreman's Signature _____

FIG. 2—SUNDAY WORKING LIST
This Form Is Used by Each Division Foreman Who Sends It Weekly to the Superintendent of Rolling Stock. That Official, in Turn, Files the Complete Report with the Department of Labor as Evidence that the State Law Requiring One Day of Rest per Week for Skilled Mechanics Has Been Complied With

TABLE 1—HOURS OF WORK OF SUPERVISORS

Day Mechanical Foreman	8:00 a.m.—6:00 p.m.
Day Mechanical Foreman's Assistant	6:00 a.m.—4:30 p.m.
Night Mechanical Foreman	6:00 p.m.—4:30 a.m.
Night Mechanical Foreman's Assistant	7:30 p.m.—6:00 a.m.

This time schedule enables the foremen and their assistants to confer regarding the work during periods in which their times overlap between the shifts.

The mechanics in the operating department are specialists and each mechanic, with an assistant, is responsible for the efficiency of a particular unit. A weekly check is kept on a personnel-record sheet, which is reproduced in Fig. 1, showing the number of men that are employed, exclusive of the foremen and the assistants, and their hours of work.

It is also necessary to keep a check on the one day of rest per week for skilled mechanics that is required by law. The form shown in Fig. 2 is used by each divisional foreman, who sends this report weekly to the office of the superintendent of rolling-stock, who, in turn, files the complete report with the Department of Labor.

In addition to the above-mentioned mechanical operating-divisions, we have two other separate divisions; the annual-overhauling shop for mechanical parts of the chassis, and the body-overhauling shop. In these shops, major repairs, in addition to the regular periodic overhauls, are made.

MILEAGE RECORDS

For the sake of convenience, every vehicle should have a number and every independent unit of that vehicle should have a number. This applies particularly to the wheels and the tires. Tire records are, of course, linked with the mileage of the vehicle, for the reason that the tires must carry the vehicle over every mile that it operates. As a consequence, the tire records are also vehicle-mileage records and can be taken care of on the form shown in Fig. 3, on which are recorded the number

of days in the month, the number of months of the year, and the front and rear-wheel numbers, with the dates on which the wheels were installed and removed; so, the mileage of each wheel and of each tire can be deduced from the daily record.

In keeping a proper record of these items, it is necessary that the person who removes a wheel from a motorbus shall make a record of it on the unit-change slip that is reproduced in Fig. 4.

Then, again, it is necessary to have a tire-change slip, for the reason that a different person removes the tire from the wheel at a different time from the removal of the wheel from the motorbus. A wheel may also be changed from one motorbus to another. These unit-change slips are sent to the mileage-clerk who transfers

FIFTH AVENUE COACH COMPANY

VEHICLE MILEAGE RECORD VEHICLE NUMBER

Date	January	February	March	April	May	June	FRONT WHEELS CHANGED
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							REAR WHEELS CHANGED
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							
31							
Total							

FIG. 3—FORM FOR RECORDING THE MILEAGE OF A MOTORBUS

The Mileage Traveled Each Day Can Be Recorded in the Proper Space at the Left, While at the Right Spaces Are Provided Wherein the Front and Rear Wheel Numbers Can Be Recorded Together with the Dates of Installation and Removal. The Back of the Card Is Ruled in the Same Way To Take Care of the Latter Half of the Year

the information contained on them to the vehicle-mileage record, which might also be called a vehicle-mileage and tire record. No necessity has appeared for keeping a record of the mileage of the inner tubes; consequently, the system explained will cover either pneumatic or solid tires.

COST OF TIRES

The cost of tires per mile may vary from 1.0 to 2.5 cents depending upon whether solid or pneumatic tires are used. It can readily be appreciated, therefore, that the operation of 400 motorbuses for an average of 35,000 miles per year each, or a total of 14,000,000 bus-miles, would represent from $140,000 to $350,000; all of which clearly shows that maintaining an accurate record of tire performance gives a control of purchasing that will enable a considerable amount of money to be saved by selecting the best tires that experience dictates.

The first fundamental requirement of a tire is resiliency, which protects the vehicle from the shocks caused by the inequalities of the roadway; the second, endurance, which relieves the operating force of the necessity for continually changing tires, or having involuntary stops in service that cause inconvenience to patrons.

FIFTH AVENUE COACH CO.

UNIT CHANGE SLIP

Authority to change a _____

Division _____ Vehicle No. _____ Date _____

No. of Unit Off _____ No. of Unit On _____

Removed by _____ Replaced by _____

CAUSE OF REMOVAL AND REMARKS

Foreman's Signature _____

This sheet must be turned into office immediately the change is made.

FIG. 4—THE UNIT CHANGE SLIP

These Slips Are the Authorization for a Mechanic To Remove Any Unit from a Motorbus. Their Use Enables an Accurate Record of the Cost of Maintaining Any Particular Unit of the Vehicle

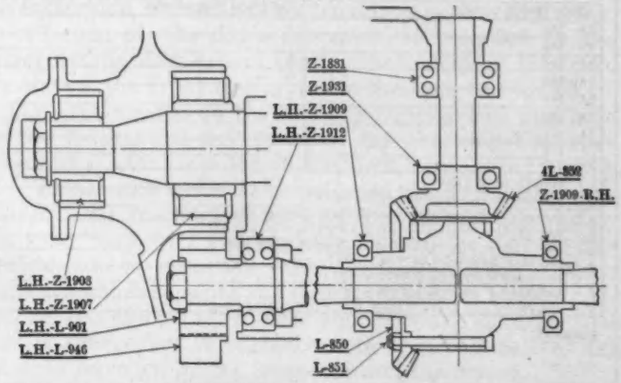
The expense of mechanical maintenance should always be linked with the depreciation account, because I am convinced that what is not spent on maintenance should be placed in a depreciation account, as a reserve that will accumulate for the early replacement of the vehicles; or, conversely, an allowance for maintenance, for keeping the vehicles in an efficient state of operation, will certainly defer the time when a large depreciation account will be necessary for the replacement of the vehicles with new ones. This, of course, does not take into consideration the factor of obsolescence, but only the ability of the vehicle to continue to operate. The cost of mainte-

FIFTH AVENUE COACH COMPANY

INSPECTION RECORD OF 4L TYPE REAR AXLE GEARS AND BEARINGS

REMOVED FROM BUS NO. ____ DIVISION ____ DATE ____ MILEAGE ____ UNIT NO. ____

MECHANIC'S NO. ____



PART NO.	DESCRIPTION	CONDITION	REPLACEMENTS
Z-1881	BEVEL DRIVE PINION AND SHAFT BEARING-OUTER		
Z-1907-L.H.	REAR WHEEL INNER BEARING		
Z-1907-R.H.	REAR WHEEL INNER BEARING		
Z-1908-L.H.	REAR WHEEL OUTER BEARING		
Z-1908-R.H.	REAR WHEEL OUTER BEARING		
Z-1909-L.H.	DIFFERENTIAL CASE BEARING		
Z-1909-R.H.	DIFFERENTIAL CASE BEARING		
Z-1912-L.H.	REAR AXLE DRIVE SHAFT BEARING		
Z-1912-R.H.	REAR AXLE DRIVE SHAFT BEARING		
Z-1931	BEVEL DRIVE PINION AND SHAFT BEARING-INNER		
L-901-L.H.	REAR AXLE DRIVE SHAFT PINION		
L-901-R.H.	REAR AXLE DRIVE SHAFT PINION		
L-946-L.H.	61 TOOTH INTERNAL GEAR RING		
L-946-R.H.	61 TOOTH INTERNAL GEAR RING		
L-850	BEVEL DRIVE GEAR		
L-851	DIFFERENTIAL BOLT		
4L-852	BEVEL DRIVE PINION AND SHAFT		

CAUSE OF FAILURE: ____

REMARKS: ____

DATE ____ INSPECTED BY ____

FIG. 5—AN INSPECTION RECORD SHEET FOR REAR-AXLE GEARS AND BEARINGS

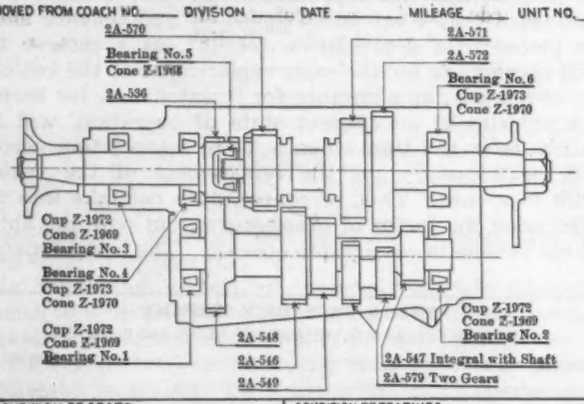
The Use of Such a Sheet Makes It a Very Simple Matter for a Mechanic Repairing This Unit To Give All the Essential Items Regarding the Unit and Its Condition and Indicate the Items That He Replaces with New Parts

nance per mile varies greatly in different localities, being affected mainly by traffic conditions and the topography of routes, which control the speed of the vehicles, and by their type and capacity, the size of the fleet, which determines the quantity of material to be purchased at a time, the overhead expense, and the like.

Because of this large expense item, it is important that cost records of the maintenance of equipment should be kept for all major repairs done in the annual-overhauling shop; but it is not necessary to go into extensive detail, particularly if only one type of vehicle is operated. The maintenance cost of vehicles may be obtained in batches that represent certain ages, that is, all vehicles put into service in the first half of the year 1923 have their repair costs, namely, the material and labor, charged to a certain shop-order number; those put into service during the second half-year have another shop-order number, and so on. The number of shop orders, on this basis, will increase with the different types of vehicles that are maintained, since it would not be fair nor instructive to group different makes together.

FIFTH AVENUE COACH COMPANY
INSPECTION RECORD OF 2A-TYPE TRANSMISSION

REMOVED FROM COACH NO.____ DIVISION ____ DATE ____ MILEAGE ____ UNIT NO.____



CONDITION OF GEARS	CONDITION OF BEARINGS
2A-536	1
2A-546	2
2A-547	3
2A-548	4
2A-549	5
2A-570	6
2A-571	
2A-572	
2A-579	

1 — CONDITION OF CASE
2 — AMOUNT OF END PLAY IN BOTTOM SHAFT
3 — AMOUNT OF END PLAY IN TRANSMISSION SHAFT (SPLINED) 2A-568
4 — WAS TRANSMISSION SHAFT PILOT BEARING TIGHT ON SHAFT?
5 — WERE CLUTCH LOCKING BEARING NUTS, PART A-539, TIGHT?
6 — WAS GEAR B TIGHT ON BOTTOM SHAFT?
7 — WAS GEAR D TIGHT ON BOTTOM SHAFT?
8 — WAS GEAR F TIGHT ON BOTTOM SHAFT?
9 — WAS PROPELLER SHAFT FLANGE, PART A-T19, TIGHT ON SHAFT?

REMARKS:

DATE _____ INSPECTED BY _____

FIG. 6—INSPECTION RECORD SHEET FOR A TRANSMISSION
Another Form of Sheet Used To Enable Accurate Data Regarding Maintenance Cost To Be Compiled Easily

MAINTENANCE OF PARTS

The cost of maintaining particular units of the vehicle is also important and is easy to obtain through the unit-change slips, if the maintenance shop is well organized and all common units are repaired by the same men in special sections. The engines should go to a definite location and be taken care of by specialists in engine-repair work; the transmissions should go to another

FIFTH AVENUE COACH CO.

Issued by	Stores Issue			Workman's No. & Initials
	Date			
Part No.	Quantity	Order or Vehicle No.	Price	Amount
Description				

To show correct material distribution mark section thus V in above column

ANALYSIS OF MATERIAL	
GENERAL	
1. Bldgs. & Fixtures	
2. Shop Tools & Sup.	
3. Service Cars	
4. Snow Eq. & Sup.	
5. Experimental	
6. Stationery	
7. Cleaning Materials	
8. Batteries	
9. Transportation	
BODIES	
10. Bodies	
11. Elec. Sup. (Bus)	
CHASSIS	
12. Axle (Front)	
13. Axle (Rear)	
14. Brakes	
15. Chassis Frames	
16. Clutch	
17. Engines	
18. Gasoline System	
19. Ignition	
20. Radiator	
21. Steering	
22. Transmission	
23. Wheels	

FIG. 7—MATERIAL REQUISITION FORM
No Material Can Be Obtained from the Storeroom without One of These Slips Approved by the Foreman Who Indicates to What Account the Material Should Be Charged

specialist, the clutches to another, the rear axles, differentials and driving-gears to others; particular records of cost should be kept in each of these specialized sections, and a differentiation made between various makes of unit.

It is important and interesting to prepare diagrams of all the main units, such as the engine, the transmission, the differential and the driving-gear assembly of the rear axle, all the wearing parts being so numbered and tabulated on the sketches that a mechanic, when repairing the unit, can take one of the sheets, two of which are reproduced in Figs. 5 and 6, record the number of the

FIFTH AVENUE COACH COMPANY
ANALYSIS OF MATERIALS AND SUPPLIES ISSUED

DAY_____ DATE_____

(TOTAL AMOUNTS FROM FIRST OF MONTH TO DATE)

		REPAIR SHOP	NO. 2 & 4 OPER. DIV.	NO. 3 OPER. DIV.	NO. 5 & 8 OPER. DIV.	TOTAL
	GENERAL					
1	BUILDINGS & FIXTURES					
2	SHOP TOOLS & SUPPLIES					
3	SERVICE CARS					
4	SNOW EQUIPMENT & SUPPLIES					
5	EXPERIMENTAL					
6	STATIONERY					
7	CLEANING MATERIALS					
8	BATTERIES					
9	TRANSPORTATION					
	BODIES					
10	BODIES					
11	ELECTRICAL SUPPLIES (BUS)					
	CHASSIS					
12	FRONT AXLE					
13	REAR AXLE					
14	BRAKES					
15	CHASSIS-MISCELLANEOUS					
16	CLUTCH					
17	ENGINE					
18	GASOLINE SYSTEM					
19	IGNITION					
20	RADIATOR					
21	STEERING GEAR					
22	TRANSMISSION					
23	WHEELS					
	TOTAL					
	MILEAGE					
	COST PER MILE					
	TOTAL NUMBER OF REQUISITIONS					

FIG. 8—ANALYSIS OF MATERIAL AND SUPPLIES ISSUED
On This Form Are Entered Daily the Quantities of Material and Supplies Issued and the Accounts to Which They Are Charged. These Entries Are the Total of the Material and Supplies Given Out by the Storeroom on the Requisition Form Reproduced in Fig. 7 The Total Amounts Issued from the First of the Month to the Day for Which This Sheet Is Made Out Appear in the Last Column

unit that he is repairing, and mark the parts that he is replacing.

Inasmuch as a unit-change slip will be made out for each unit at the time that it is removed from the vehicle, the number of the motorbus and the date will be given, and a second change slip will cover the installation of another unit to replace that removed, the length of service of each unit can be computed. By referring to the vehicle-mileage record, shown in Fig. 3, the mileage can be deduced for a particular unit, from the date of its installation to that of its removal. In this way, the quality of the material acquired by the purchasing department, as well as the efficiency of the design, may be checked. If there is an isolated case in which an amount of trouble in excess of the normal amount is shown on a particular unit, the trouble can be traced to the inefficiency of the driver. The point is, that, whatever may occur, the efficiency or the inefficiency can be attributed to some one or to some thing. It may be caused by a poor driver, poor mechanical maintenance, poor material or inferior design, all of which must be remedied if the person or the company controlling the vehicle is to operate in an efficient and profitable manner.

FIFTH AVENUE COACH CO., N. Y.

BUS REPORT CARD

Bus No._____ Date_____

THIS CARD MUST BE LEFT ON BUS ALL DAY

TIME	NATURE OF DEFECT	BADGE No.

EVERY DR. AND CONDUCTOR WILL ENTER DETAILS AS TO ANY APPARENT DEFECT. IF NO DEFECT EXISTS, MARK O.K. IN DEFECTS COLUMN, ALSO TIME LEAVING BUS AND BADGE NUMBERS IN COLUMNS PROVIDED.

BRAKE DEFECTS

MARK X AGAINST DEFECT YOU WANT REMEDIED

	FOOT BRAKE	HAND BRAKE
Binding		
Equalize		
Locking		
Sticking		
Squeaking		
Tighten		

FIG. 9—FRONT OF THE BUS REPORT CARD

This Card, Which Must Be Left on the Bus All Day, Provides a Means for Reporting All Defects in Equipment and Gives a Record of All the Employes Who Manned the Vehicle and the Time at Which They Turned It over to Another Crew

RECORD OF DELAYS

BADGE NO.	RUN NO.	POINT	TIME	MIN'S LOST	NATURE OF REPAIR OR ADJUSTMENTS

ENTRIES MUST BE MADE ABOVE FOR ALL DELAYS, REPAIRS, ADJUSTMENTS, TELEPHONE CALLS AND BUS CHANGES REGARDLESS OF DURATION OR WHETHER MADE DURING STANDTIME

FIG. 10—BACK OF THE BUS REPORT CARD

On This Side Spaces Are Provided To Give a Complete Record of All Delays, Including Where and When They Occurred, the Time Lost and What Adjustments or Repairs Were Made

In the shops of the Fifth Avenue Coach Co., all material is obtained through requisitions, the form used being illustrated in Fig. 7. These requisitions are signed by the foreman, who notes in the column headed Analysis of Material the account to which the material should be charged, so that the full quantities can be allocated to the units and to the divisions using it. The accumulated data for the month are summarized on the form shown in Fig. 8. In this manner, the cost of material and labor for operating maintenance can be computed from the data recorded on the Analysis of Material and Supplies Issued and the Personnel Establishment form, reproduced in Fig. 1.

FILLING STATIONS

Each garage unit should have at least two gasoline-filling and oiling stations located at sufficient distances within the garage entrance to allow several motorbuses to enter at one time. The gasoline pumps should have a capacity of at least 20 gal. per min. While the attendants are supplying gasoline, oil and water to the motorbus, the driver, with the help of the assistant night foreman of the garage, who is the official inspector, makes a general inspection of the motorbus, paying particular attention to the steering-gear and levers, the springs and the brakes. For this work the driver is paid. The result of the inspection, as well as any trouble experienced during, or criticism of, the day's operation, is recorded by the driver on the Bus Report Card. Both sides of this card are shown, the front in Fig. 9 and the back in Fig. 10.

The information on the cards is summarized and used by the mechanical day foreman for checking the work done. It is also recorded on the form reproduced in Fig. 11. These data serve as a guide to the specialized mechanics. No mechanical work is done at night except by the road mechanic, who remains on duty as long as any vehicles are in operation. The man who makes a repair signs the sheet opposite the item on which he worked. He also reports the actual trouble and the work done, because this is frequently at variance with the diagnosis of the fault as reported by the inspector and the driver.

Besides the inspection made by the drivers and the inspectors, a weekly inspection and report are made on each major unit, such as (*a*) the rear axle, (*b*) the engine, (*c*) the clutch, (*d*) the body, (*e*) the front axle and steering-

FIFTH AVENUE COACH CO.

REPORT OF BUSES BOOKED FOR REPAIR

DIVISION_____ DATE_____

BUS NO.	TIME OUT	MECHANIC'S NIGHT REPORT	CAUSE OR ACTUAL TROUBLE

*Signature*_____

FIG. 11—REPORT OF BUSES BOOKED FOR REPAIR

The Entries Regarding Defects on the Bus Report Cards Are Transferred to This Form. The Mechanic Correcting Any Defect Signs His Name Beside the Item on Which He Worked and Reports the Actual Trouble and the Work Done. Frequently the Former Is Different from the Fault Reported by the Inspector and the Driver

levers, (*f*) the transmission and (*g*) the propeller-shafts. This work is done by the assistant night foreman, who is the official inspector and is relieved or assisted by the road mechanic, the inspection being made after the motorbuses have been stored in the garage.

All records on the form reproduced in Figs. 9 and 10 for each particular motorbus are sent to the division clerk, who tabulates the information on the Drivers' Report and General-Overhaul Sheet illustrated in Fig. 12. This sheet covers the entire performance of the motorbus for approximately 2000 miles, after which the motorbus is held in the shop for about 5 hr. to undergo a general overhauling. Complete inspection is made as outlined on the sheet, each mechanic, after doing his part, signing his name in the section that applies to his work. The whole record is checked and finally signed by the mechanical operating foreman, and is filed in the research department for future use.

Night Force

The organization of a night force is just as important as is that of a mechanical day force. In our case, in

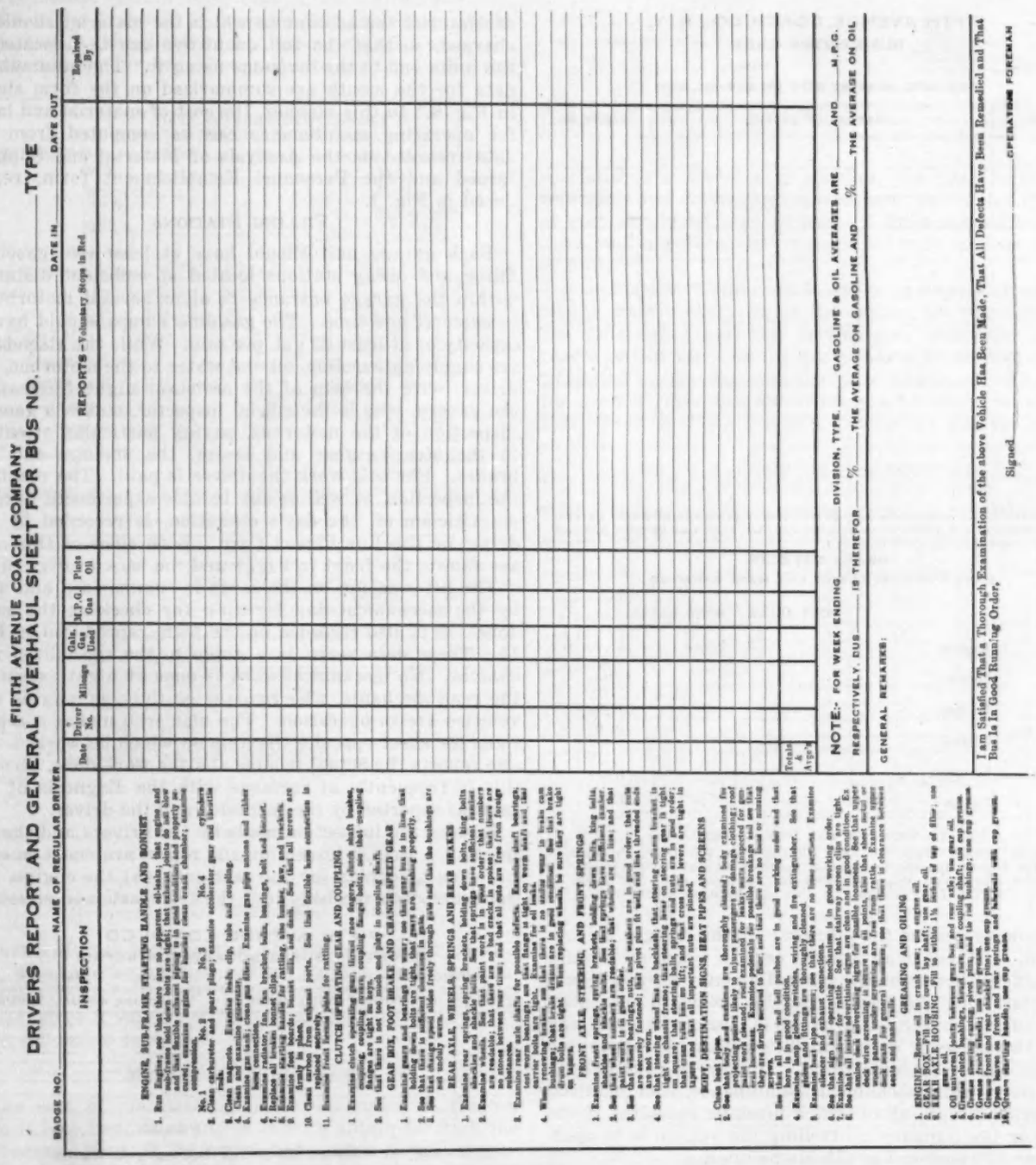

FIFTH AVENUE COACH COMPANY
DRIVERS REPORT AND GENERAL OVERHAUL SHEET FOR BUS NO. ____ TYPE
BADGE NO. ____ NAME OF REGULAR DRIVER ____ DATE IN ____ DATE OUT
INSPECTION
REPORTS—Voluntary Stops in Red
Date
Driver No.
Mileage
Gals. Gas Used
M.P.G. Gas
Pints Oil
Repaired By
ENGINE, SUB-FRAME, STARTING HANDLE AND BONNET
1. Run Engine; see that there are no apparent air-leaks, that engine and engine-supports are tight, that all nuts and bolts are in good condition and that flexible exhaust piping is in good condition; and properly secured; examine engine for knocks; clean crank chamber; examine compression. No. 1 No. 2 No. 3 No. 4 cylinders
2. Clean carburetor and spark plugs; examine accelerator gear and throttle rod.
3. Clean magneto. Examine body, clip, tube and coupling.
4. Clean and examine generator.
5. Examine gas tank; clean gas filter. Examine gas pipe unions and rubber hose connection.
6. Examine radiator, fan, fan bracket, bolts, bearings, belt and bonnet.
7. Replace all broken bonnet clips.
8. Examine starting handle for rattling, axe, bushes, jaw, and brackets.
9. Examine gas boards; bonnet sills, and sash. See that all covers are firmly in place.
10. Clean carbon from exhaust ports. See that flexible hose connection is replaced securely.
11. Examine front frame plate for rattling.
CLUTCH OPERATING GEAR AND COUPLING
1. Examine clutch operating gear, thrust race fingers, clutch shaft bushes, and shackle bolts. See that springs have sufficient tension.
2. Examine universal coupling flange bolts; see that coupling flanges are tight in keys.
3. See that there is not too much end play in coupling shaft.
GEAR BOX, FOOT BRAKE AND CHANGE SPEED GEAR
1. Examine gears and bearings for wear; see that gear box is in line, that holding down bolts are tight, that gears are working properly.
2. See that change speed lever is in its correct position.
3. See that change speed slides freely through slow and that the bushings are not unduly worn.
REAR AXLE, WHEELS, SPRINGS AND REAR BRAKES
1. Examine rear springs, spring brackets, holding down bolts, king bolts shackles and shackle bolts. See that springs have sufficient tension.
2. Examine rear wheels; see that spokes are not loose, that felloes are not cracked, that there are no bad cracks in spokes; that there are no stones between rear tires, and that all nuts are free from foreign substances.
3. Examine rear axle shafts for possible defects. Examine shaft bearings, test worm bearings; see that flange is tight on worm shaft and that carrier bolts are tight. Examine for oil leaks.
4. When necessary, adjust brake shoes. See that worm in brake cam is tight and that brake shoes are in good condition. See that brake drum bolts are tight. When replacing wheels, be sure they are tight on taper.
FRONT AXLE, STEERING, AND FRONT SPRINGS
1. Examine front springs, spring brackets, holding down bolts, king bolts, shackles and shackle bolts. See that springs have sufficient tension.
2. See that wheels are roadable; that wheels are in line; and that paint work is in good order.
3. See that wheel bearings, nuts, and washers are in good order; that nuts are not worn, fastened; that pivot pins fit well, and that threaded ends are not worn.
4. See that steering wheel has no backlash; that steering column bracket is tight on chassis frame; that ball, spring and nuts are in good order; that cross tube has no lift; and that cross tube levers are tight in tapers and that all important nuts are pinned.
BODY, DESTINATION SIGNS, HEAT PIPES AND SCREENS
1. Clean boot pipes.
2. See that body and cushions are thoroughly cleaned, body examined for paint work cleaned; roof examined for leaks; seats inspected for gum; rail loosened. Examine pedestals for possible breakage and see that they are firmly secured to floor; and that there are no loose or missing rivets.
3. See that all bells and bell pushes are in good working order and that lamps are in good condition.
4. Examine destination signs, wiring and fire extinguisher. See that plates and fittings are thoroughly cleaned.
5. Examine heat pipe screens; see that there are no loose sections. Examine silencer and exhausting mechanism is in good working order.
6. See that stairway screen clips are tight.
7. Examine windows for rattle. See that stairway screen clips are tight.
8. See that all inside advertising cards are clean and in good condition. Examine outside advertising cards; see that they are clean and in good condition; that wire screening is secure at all points, also that sheet metal or wood panels under screening are free from rattle. Examine upper deck seats for general looseness; see that there is clearance between seats and lower deck.
GREASING AND OILING
1. ENGINE—Power oil to crank case; run engine oil.
2. GEAR BOX—Fill up to cross bar shaft; use gear oil.
3. REAR AXLE HOUSING—Fill to within 1½ inches of top of filler; use gear oil.
4. Oil and grease joints between gear box and rear axle; use gear oil.
5. Grease clutch bushes, thrust race, and coupling shaft; use cup grease.
6. Grease steering casting, pivot pins, and tie rod bushings; use cup grease.
7. Grease front wheels; use cup grease.
8. Grease rear wheels; use cup grease.
9. Open hoods; oil front and rear springs and shackles with cup grease.
10. Grease starting handle; use cup grease.
Totals & Avgs.
NOTE:- FOR WEEK ENDING ____ DIVISION, TYPE. ____ GASOLINE & OIL AVERAGES ARE ____ AND ____ M.P.G.
RESPECTIVELY. BUS ____ IS THEREFOR ____% ____ THE AVERAGE ON GASOLINE AND ____% ____ THE AVERAGE ON OIL
GENERAL REMARKS:
I am Satisfied That a Thorough Examination of the above Vehicle Has Been Made, That All Defects Have Been Remedied and That Bus Is In Good Running Order,
Signed ____
OPERATING FOREMAN

Fig. 12—Drivers Report and General Overhaul Sheet

The Information from the Bus Record Card Reproduced in Figs. 9 and 10 Is Transferred to This Sheet Which Records the Entire Performance of the Bus over Approximately 2000 Miles, after Which the Bus Is Held in the Shop for about 5 Hr. To Undergo Its General Overhaul. A Complete Inspection as Outlined in the Lower Part of the Form Is Made and Each Mechanic Signs in the Section Applying to His Work after He Has Finished. The Mechanical Operating Foreman Checks and Signs the Sheet after Which It Is Filed in the Research Department for Future Use

FIFTH AVENUE COACH COMPANY

GASOLINE ISSUE AND CONSUMPTION SHEET

DAY_____ 192 DIVISION_____

CONSUMPTION						ISSUE			CONSUMPTION						ISSUE			CONSUMPTION						ISSUE		
Bus No.	Prev. Day Read.	First Read.	Gas Used	Miles Oper.	Aver. Mi. per Gal.	Second Read.	Road Issue	Total Issues	Bus No.	Prev. Day Read.	First Read.	Gas Used	Miles Oper.	Aver. Mi. per Gal.	Second Read.	Road Issue	Total Issues	Bus No.	Prev. Day Read.	First Read.	Gas Used	Miles Oper.	Aver. Mi. per Gal.	Second Read.	Road Issue	Total Issues

PRIVATE CARS, TRUCKS, TESTS AND SALES

SIGNED_____
NIGHT FOREMAN

FIG. 13—GASOLINE ISSUE AND CONSUMPTION SHEET

This Sheet Provides Spaces for Recording the Quantity of Gasoline in the Fuel Tank at the Beginning of the Day's Work, the Quantity Remaining at the End of the Day, the Gasoline Consumption, the Mileage Covered and the Average Mileage per Gallon. Spaces Are Also Provided for the Gasoline Issued on the Road so That the Total Quantity of Gasoline Issued Can Be Allocated to the Mileage Covered. Such a Sheet Will Record This Information for 135 Buses

which each division includes approximately 100 motorbuses that are arriving at frequent intervals during the night, the motorbuses must be gassed, oiled and placed in their positions for the night, so that they will be able to get out in the morning without moving a half-dozen other motorbuses; and last, but not least, they must be cleaned. Each motorbus must be thoroughly swept out and its windows, brasswork and hand-rails cleaned each night. After rainy days, the mud splashes must be washed from the wheels and lower portions of the body, but during fine weather a schedule must be arranged that will provide for wet washing both inside and outside every few days. As this schedule calls for the washing of some motorbuses in each division every night, the designated motorbuses are put into certain locations by the placer, after the driver has left the vehicle at the gasoline-filling and inspection station. At the end of the night's work, the foreman inspects these motorbuses and checks them on a master sheet that records the number of each motorbus and the date on which it was last washed. The dry cleaning work, such as sweeping the floors and cleaning the windows and brasswork, is inspected by the assistant night foreman every half-hour, the night force being divided into gangs, to each of which are allocated certain motorbuses having selected numbers.

GASOLINE CONSUMPTION

Consumption of gasoline is an important item and should be given considerable attention by owners of large fleets. In the East, the average price of gasoline is approximately 21 cents per gal. Assuming the remarkable average of 7 miles per gallon, the cost per mile for gasoline is 3 cents. Assuming an average mileage of 35,000, the gasoline would cost $1,050 per year per vehicle. For a fleet of 400 vehicles, the annual cost of gasoline would be $420,000. You can readily appreciate that an experienced mechanic, who can keep in proper shape the carbureter adjustments, magnetos and spark-plugs and maintain the general condition of the engine will easily save not only his own salary but much expense desides.

Because of the monetary value of gasoline consump-

FIFTH AVENUE COACH COMPANY

SUMMARY OF GASOLINE CONSUMPTION

WEEK ENDING_____

	No. 2 Garage 133rd Street	No. 3 Garage 102nd Street	No. 4 Garage 133rd Street	Nos. 5 & 8 Garage 132nd Street
NO. OF BUSES OPERATED				
This Week				
Last Week				
Last Year				
DISTRIBUTION OF BUSES				
"A" Type This Week				
Last Year				
"L" Type This Week				
Last Year				
"J" Type This Week				
Last Year				
EARNINGS PER BUS MILE				
This Week				
Last Week				
Last Year				
NO. OF MILES OPERATED				
This Week				
Last Week				
Last Year				
AMOUNT OF GAS CONSUMED				
This Week				
Last Week				
Last Year				
DIVISIONAL GAS AVERAGE				
This Week				
Last Week				
Last Year				
TYPE AVERAGE BY DIVISION				
"A" Type This Week				
Last Year				
"L" Type This Week				
Last Year				
"J" Type This Week				
Last Year				
INDIVIDUAL AVERAGES				
"A" Type Highest				
Second Highest				
Lowest				
Second Lowest				
"L" Type Highest				
Second Highest				
Lowest				
Second Lowest				
"J" Type Highest				
Second Highest				
Lowest				
Second Lowest				

	THIS WEEK	LAST WEEK	LAST YEAR
Total Average			
Total Number of Buses			
Price of Gasoline			
Total Amount of Gas Consumed			
Total Miles Operated			
Total Earnings Per Mile			
Average Temperature			

FIG. 14—WEEKLY SUMMARY OF GASOLINE CONSUMPTION

A Close Check on Gasoline Consumption Is Afforded by This Form Which Gives a Comparison of the Week in Question with the Preceding One and the Corresponding Week of the Year Before

FIFTH AVENUE COACH COMPANY
DAILY TELEPHONE CALLS

DATE _____ 192__

BUS NO.	TIME RECD.	LOCATION OR DIRECTION	TIME AT M.T.	NATURE OF CALL	RECD. BY	PHONED BY	REPAIRED BY

FIG. 15—RECORD OF TELEPHONE CALLS RECEIVED FROM DRIVERS
When an Involuntary Delay to a Bus Occurs, the Driver Telephones for Help. Such Calls Are Entered on This Form Which Serves as a Check on the Promptness with Which Mechanics Respond and Remedy the Defect

tion, a very close check should be made on both the receipts and the disbursements of gasoline. The main gasoline-storage tanks should be designed so that a quantitative reading can be obtained. Measurements of the quantity of gasoline in the tanks before and after the oil company has delivered a load should be made, and the difference should be compared with the receipt given to the oil company's representative.

The quantity of gasoline in the tanks should be measured at the end of each day, after all the disbursements have been made, so that the difference between this reading and the reading made after the delivery of gasoline from the source can be compared with the total amount of gasoline disbursed during the day. When gasoline is being continually delivered to vehicles in quantities of from 10 to 30 gal., minor discrepancies of fractional parts of a gallon will frequently occur, the accumulation of which over a period of a week may amount to a large quantity; and, whenever men are allowed to write-off a quantity of material to balance their records, a chance is offered for somebody to become careless in the disbursement.

To check the condition of the engine or the possible carelessness of a driver, a reading should be made of the quantity of gasoline in the tank of each vehicle when it reaches the garage at night. This reading should be placed on the sheet reproduced in Fig. 13, on which is recorded the quantity of gasoline in the tank after it had been filled on the previous night. The difference between these items will give the gasoline consumption for the day. By referring to the mileage record of the vehicle, the average miles per gallon can be calculated. A column is provided on this record for the gasoline issued on the road, so that the total amount of gasoline issued can be allocated to the mileage performed.

This may seem to entail a large amount of work and detail; and it is admitted, of course, that the system must contain a certain number of vehicles in order that the economy obtained may be sufficient to justify its installation. Other advantages, however, are to be gained from keeping so close a record. The gasoline consumption of a motor vehicle is a true indication of the condition of the engine and of the ability of the driver. A consistently good gasoline average invariably proves that the vehicle is in the hands of a competent, careful and conscientious driver and that the mechanism is in a state of efficiency that will reflect credit on the system of mechanical maintenance. For instance, if the cylinder-walls are worn, the pistons and the piston-rings need replacing, the valves need reseating, or the brakes bind, these facts

FIFTH AVENUE COACH COMPANY
ROAD MECHANICS REPORT

DATE _____ 19__ DIVISION _____

BUS NO. _____ DRIVER _____ BADGE _____

TIME NOTIFIED _____ AT _____ BY _____

TIME LEFT GARAGE _____ DESTINATION _____ TIME REACHED _____

NATURE OF TROUBLE _____

TIME STARTED REPAIRS _____ TIME FINISHED REPAIRS _____ THE BUS CONTINUED OPERATION _____

REPAIRS MADE _____

COULD DRIVER HAVE MADE REPAIRS? _____

DID DRIVER MAKE ANY REPAIRS? _____ WHAT DID DRIVER DO TO OVERCOME TROUBLE? _____

TIME REPORTED BACK TO GARAGE _____

THIS FORM MUST ONLY BE MADE OUT WHEN BUS IS STOPPED FOR MORE THAN 5 MINUTES

SIGNED _____
ROAD MECHANIC

FIG. 16—ROAD MECHANICS REPORT
When a Bus Is Stopped for More than 5 Min., This Report Form Giving All Pertinent Facts in Connection with the Involuntary Delay Is Filled Out by the Road Mechanic

FIFTH AVENUE COACH COMPANY
INVESTIGATION OF INVOLUNTARY STOP

_____ Division Date of Stop _____ Day _____ 19__

Driver's Name _____ Badge _____ Conductor's Name _____ Badge _____

'Bus No. _____ Time _____ A P M to _____ A P M Total _____ Minutes

Time Garage 'Phoned _____ A P M Time Mechanic Arrived _____ A P M Repair Finished _____ A P M

Directions _____ Location _____

Inspector on Post _____ Time he arrived _____ A P M

Mechanic's Report _____

FIG. 17—INVESTIGATION OF INVOLUNTARY STOP
If Involuntary Delays Occur Frequently or Are Serious, a Joint Investigation Is Made by the Mechanical and Transportation Superintendents of the Division. This Investigation Permits Steps To Be Taken To Avoid a Repetition of the Trouble

will become evident, to the detriment of the gasoline consumption. In our experience, this is an item that cannot be neglected. To keep a close check on the gasoline-consumption records, the form illustrated in Fig. 14 is issued weekly.

OIL CONSUMPTION

Oil consumption is an extremely important item, for, without proper and adequate lubrication, the life of the vehicle will be reduced at a high rate. The main unit in a vehicle that requires proper lubrication is, of course, the engine, which alone can be conservatively estimated as worth not less than $1,000, and probably more.

The consumption of oil varies with the mechanical condition of the engine and can be controlled by the proper and timely adjustment of the crankshaft bearings, replacement of the piston-rings, and attention to the proper sealing of joints with gaskets.

Users and manufacturers report the oil consumption as varying from 200 to 1000 miles per gal. The writer has had experience with this extreme variation but, for the sake of comparison, let us take an average of 300 miles per gal. and assume the average cost of a first quality lubricating oil to be 50 cents per gal. Obviously, then, the cost per mile will be 0.16 cent, or, for an average of 35,000 miles per year, $56 per engine; or, for a fleet of 400 vehicles, $22,400.

Here we have an item on which we cannot afford to

economize under any circumstances. When one realizes that the average temperature inside an engine that is operating from 10 to 20 hr. per day is about 250 deg. fahr., that the viscosity of the oil at that temperature must be as high as possible, that the oil plus the piston-rings is relied upon to prevent the gasoline vapor from blowing by the piston into the engine crankcase and there condensing and mingling with the oil, still further reducing the viscosity and increasing the flash-point of the oil, is it not obvious that it is foolhardy to attempt to reduce an item of $22,400 for lubricating oil by 10 per cent and to reduce correspondingly the useful life of $400,000 worth of engines?

The way to economize on this item is to increase the expenditure for oil by obtaining the finest quality available and to cause strict watch to be kept on its consumption because, whenever an engine exceeds the average oil-consumption, it is highly probable that it is time that the piston-rings should be changed or some other mechanical adjustment made.

In recording the average oil-consumption of vehicles, the same form can be used as that for recording the gasoline consumption, shown in Fig. 13, and the heading can be changed to fit the case.

Involuntary Delays

In spite of careful inspection and timely overhauls, some vehicles may suffer from involuntary delays through various causes. The involuntary-delay record is the key to the efficiency of the operating department; a strict account of the time lost because of involuntary stops is therefore necessary.

FIFTH AVENUE COACH COMPANY

TRANSPORTATION DEPT.

DAILY REPORT OF DELAYS

DAY 192

DIV.	BUS NO.	TIME STOPPED	MIN. LOST	DRIVER	DATE OF LAST G.O.	LOCATION	REMARKS	REP. BY

CODE:-

If repaired by Driver on road mark "D"
If repaired by Driver at terminal mark "DT"
If repaired by mechanic on road mark "M"
If repaired by mechanic at terminal mark "MT"
If mechanic takes bus to terminal to make repair mark "BMT"
If mechanic takes bus on road mark "BM"
If bus is changed mark "CB"

Signed

Fig. 18—Daily Report of Delays

This Form, Copies of Which Are Distributed to All Officials and Superintendents, Summarizes the Involuntary Stops Made Each Day. The Cause of the Trouble Is Entered in the "Remarks" Column

All telephone calls from drivers of motorbuses are recorded on a special form that is reproduced in Fig. 15. These serve as a check on the promptness of mechanics to respond to the call and to remedy the defect. These delays are also recorded on the back of the Driver's Day Card, shown in Fig. 10. When the involuntary delay is of longer duration than 5 min., the mechanic makes a report on the Road Mechanic's Report, illustrated in Fig. 16. Depending upon the frequency or seriousness of the delay, an investigation is made jointly by the mechanical and the transportation divisional superintendents, who report on the form, the front of which is reproduced in Fig. 17. Spaces are provided on the back for recording the date and place of the investigation, those present and the conclusions reached or the recommendations made. This joint investigation allows further instruction of the driver or other action, to avoid a repetition of the trouble.

WEEKLY ANALYSIS OF DELAYS

WEEK ENDING

At Fault	Rear-Axle Assembly	Body	Brakes	Clutch	Engine	Gas System	Ignition	Springs	Transmission	Totals	Per Cent
Material											
Division #4											
Division #5 & 8											
Division #2											
Division #3											
Totals											
Per Cent											

(Stopping of a bus in service for one minute or more is considered to be an involuntary delay)

Fig. 19—Weekly Analysis of Delays

A Comparative Statement of Involuntary Delays and Their Causes Is Compiled on This Form, Which Allocates the Responsibility for the Delay to Either the Mechanical or the Transportation Superintendent of the Division or to the Quality of Material or a Deficiency of Design. These Statements Are Also of Service to the Engineering Department when New Designs Are Contemplated Since They Indicate What Particular Unit of the Bus Has Caused Trouble and Is in Need of Improvement

A daily summary of these stops is made and distributed to all officials and superintendents on the Daily Report of Delays, which is shown in Fig. 18. In the column for Remarks is given the cause of the trouble.

In addition to the daily summary of involuntary delays, comparative statements are made weekly and monthly of the causes of such delays, these records being compiled on the form reproduced in Fig. 19, in which the responsibility for the delay in question is allocated to either the transportation or the mechanical superinten-

FIFTH AVENUE COACH COMPANY

COMPARISON OF DELAYS ON ALL TYPES OF BUSES IN F. A. C. SERVICE

FOR THE MONTH OF

	"L" TYPE		"2L" TYPE		"J" TYPE		"A" TYPE		TOTALS	
	No. of Stops	Miles per Delay	No. of Stops	Miles per Delay	No. of Stops	Miles per Delay	No. of Stops	Miles per Delay	No. of Stops	Miles per Delay
Rear Axle Assembly										
Body										
Brakes										
Clutch										
Engine										
Gas System										
Ignition										
Miscellaneous										
Springs										
Transmissions										
Totals										
Average No. of Buses in Service										
Mileages										

(Stopping of a bus in service for one minute or more is considered to be an involuntary delay)

Fig. 20—Semi-Annual Analysis of Involuntary Delays

This Form, Which Is Compiled from the Various Records Relating to Involuntary Delays, Shows the Number of Stops of More Than 1-Min. Duration Caused by Each Particular Unit of Each Type of Vehicle and the Number of Miles per Stop

dent of the division, or to the quality of the material or the deficiency of the design. A close check of this summary, as compared with that of any previous period, will give a comparison of the efficiency of the organization. This is a guide for the engineering department, when they contemplate making new designs, for obviously it indicates the particular unit of the motorbus that has caused trouble and is in need of improvement.

Every half-year, an analysis is made from these records that shows the number of stops because of each particular unit of each type of vehicle, and the number of miles per stop. A sample record of this data is illustrated in Fig. 20.

Conclusion

No reference has been made to the thorough and extensive organization required for the operation of snowplows and sand-trucks, which are under the jurisdiction of the transportation division. The mechanical maintenance of such vehicles is carried out in a manner similar to that appertaining to motorbuses, except that, as the operation of non-revenue service vehicles is infrequent, it is not possible to designate for them a periodic inspection or overhauling. In the winter season, however, whenever snowstorms threaten, whether by day or by night, it is the duty of the force in charge of the plows to start the engines and to inspect them, to make sure that they are ready for immediate operation.

This paper covers only the phases of the mechanical supervision of motorbus operation in vogue in the organization of the Fifth Avenue Coach Co. Many other divisions, such as transportation, material supplies and purchasing, auditing, construction, cost accounting, and the like, are problems in themselves and would require separate consideration in order that each individual section should be covered.

WHEEL SHIMMYING—ITS CAUSES AND CURE

A CORRECTION should be made in the paper with the above title by Otto M. Burkhardt, consulting engineer of the Pierce-Arrow Motor Car Co., Buffalo, that appeared in the February issue of THE JOURNAL. This applies to the reference letters in Fig. 4 and equations (1) and (2) referring thereto as printed on p. 191.

The proper illustration is presented herewith and the equations in their correct form are given below:

$$F_1 = F(b + x)/c = F(b/c) + F(x/c) \quad (1)$$
$$F_2 = F(b - x)/c = F(b/c) - F(x/c) \quad (2)$$

In the paragraph preceding the equations the expression for the forces should have been $F\ (b/c)$ and not $F\ (c/d)$ as printed.

Another error was allowed to find its way into THE JOURNAL. The final question following the substitution of numerical values for b and x in equations (1) and (2) should have a minus sign preceding the last member. This is, of course, obvious from the substitution and also from the text immediately following this equation near the top of the second column on p. 191.

Unusual efforts to print as many of the Annual Meeting papers as possible in the February issue were largely responsible for these unfortunate errors.

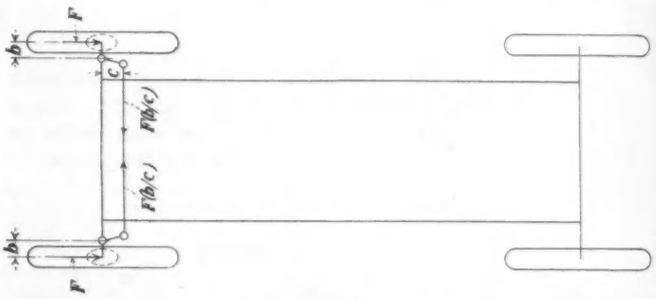


FIG. 4—DIAGRAM FOR ANALYZING WHEEL SHIMMYING

This Drawing Represents a Plan View of a Primitive Chassis; the Dotted Areas under the Front Wheels, the Tire Contact; and F, the Road Resistance or the Retarding Force or Both. On a Perfectly Smooth Road Two Equal and Opposite Forces $F(b/c)$ in the Tie-Bar Hold Each Other in Equilibrium. If However a Lateral Sway of the Chassis Changes the Lever Arm b, the Forces then Differ by an Amount $2F(x/c)$ Which Causes the Wheels To Deviate in One Direction. As the Chassis Swings Back the Force Passes through Zero to the Maximum in the Opposite Direction, Causing the Wheels To Deviate in the Opposite Direction. These Alternating Forces Cause Shimmying unless Everything Is Fitted So Snugly That These Forces Are Prevented from Gathering Momentum

CENSUS OF MANUFACTURES FOR 1923

THE Bureau of the Census puts the total value of the products of all manufacturing industries in the United States in 1923, omitting the products of manufacturing establishments whose output was valued at less than $5,000, at the sum of $60,481,135,000, this total comparing with $43,653,283,000 for the census year 1921, with $62,041,795,000 for the census year 1919 and with $23,987,860,000 for the census year 1914.

The value total of manufacturing production in 1919 is necessarily much affected by the excessively high prices obtaining in that year, whereas the general price-level in 1923, even if much higher than the prewar price-level, was still at a much more moderate height than that of 1919. The conclusion arrived at by the Census Bureau is that, measured in quantities, not values, the actual output of American manufactures in 1923 was approximately 19 per cent greater than the output in 1919.

In no other year in the entire history of the Country has the sum-total of actual value created by our manufacturing industries been so great as it was in 1923. The actual value created by manufacture in 1923 exceeded that of 1919 by about $1,100,000,000.

Powerful economic influences are now operative in the United States tending to a concentration of manufacturing industry in a continuously smaller number of plants of larger capacity. The process of industrial concentration has been both continuous and rapid throughout the past decade. The manufacturing industries of the United States, though employing 10 per cent fewer establishments, 12 per cent fewer salaried officers and employees, and 2¾ per cent fewer wage-earners in 1923 than in 1919, yet produced in 1923 a total output greater by 19 per cent in quantity than that of 1919.

This increase in efficiency was attended by a very considerable increase in the average remuneration of the wage-earning workers in industry; for in 1919 the total wage-earning group of 9,000,059 workers received a total compensation of $10,461,787,000, while in 1923 the wage-earners numbering only 8,763,233 received a total compensation of $10,985,805,000.—A. R. Marsh in *Economic World.*

Vol. XVI March, 1925 No. 3

Measuring the Percentage of Crankcase-Oil Dilution

By T. S. Sligh, Jr.[1]

Annual Meeting Paper *Illustrated with* Drawings

ABSTRACT

VARIOUS methods of measuring the percentage of diluent in used crankcase oils are summarized in this paper but the broader questions of deterioration of the oil due to other factors are not considered. The characteristics of viscometric methods and of steam-atmospheric and vacuum-distillation methods are discussed. It is pointed out that as dilution is not the only change the oil undergoes in service, methods based upon the assumption that oil is unchanged except by the presence of diluent may yield misleading results.

Distillation methods seem best suited for this determination and those which are rational, in that the evaluation of the diluent is based on the change in the properties of the distillate as the distillation proceeds from diluent to oil, seem to promise the greatest accuracy over a wide range of diluents and oils.

Since the accuracy that is necessary for research work is not attainable with the simple apparatus and procedure desirable for general routine work, two rational methods are suggested for the determination of percentage of crankcase-oil dilution. The first is a vacuum-distillation method carried on at a pressure low enough, about 4 cm. (1.575 in.) of mercury, to avoid cracking of the oil. In this method distillation data, volume of distillate and vapor temperature are taken and the percentage of diluent deduced from these data or from a curve plotted from the data. The results are accurate to within about ½ of 1 per cent.

The second method is a rapid atmospheric distillation in which no thermometer is used. The distillate is fed from the condenser through a funnel having a capillary section in the stem. The transition from diluent to oil is accompanied by an abrupt increase in viscosity of the distillate and also in the rate of distillation with constant heat-input. These two effects combine to produce a rapid rise in the head of distillate in the capillary section. The volume of distillate corresponding to this rapid increase is taken as the diluent. Results may be expected to fall within 2 per cent of the true value.

THE problem of measuring the percentage of diluent in crankcase oils has received considerable attention in the last few years and a number of different methods of making this measurement has been in use. When dilution occurs the viscosity of the oil is decreased. It is important for some purposes to know the actual *viscosity* of the diluted oil; for other purposes it is highly desirable to know the *percentage of dilution*. The latter factor will be discussed in this paper and a summary and comparison of methods of measuring crankcase-oil dilution will be given without, however, presenting a critical study of details.

A brief consideration of the changes that an oil undergoes in internal-combustion-engine service will be of interest as a background for this presentation. An oil of more or less suitable viscosity is placed in the crankcase of an automobile engine and is distributed by the lubricating system to the various bearings and the cylinder-walls. The oil on the cylinder-walls comes into rather intimate contact with the incoming charge of fuel, some of which it absorbs, and also with the dust, silica, moisture and other impurities drawn in with the air. This film of oil, exposed to the heat of explosion, takes up some oxygen, and some of the oil that exists as spray in the combustion-chamber probably is burned. The oil that reaches the hotter parts of the combustion-chamber, as the piston-head, cooks down to a gummy mass and, together with the road dust that may come into contact with these surfaces, forms the so-called "carbon" in the combustion-chamber.

The diluted oil, dust and free carbon eventually reach the crankcase, together with particles of metal that may be present because of abrasion or imperfect cleansing. In the crankcase the oil, as a fine spray, is further exposed to oxygen and is churned up with what water may have found its way into the crankcase from the combustion-chamber. It seems improbable that any appreciable amounts of volatile cracked products are present, as these most likely would be formed in the combustion-chamber and either burned or swept out with the exhaust gases. The used oil drawn from the crankcase may consist of lubricating oil, heavy ends of the fuel, oxidation products such as petroleum acids and asphaltenes, free carbon, road dust and abraded metal particles. Contrary to the common mode of expression, the oil does not "break down," that is, thin out in service. As a matter of fact, the natural tendency is for the viscosity of the oil to increase. This effect is, however, usually masked by the presence of fuel diluent.

Methods That Have Been Proposed

Some of the methods that have been proposed for measurement of the percentage of fuel diluent are:

(1) Comparison of the viscosity of the used oil with that the new oil when diluted with various percentages of diluent

(2) Comparison of its specific gravity with that of the diluted new oil

(3) Comparison of its flash-point with that of the diluted new oil

(4) Atmospheric distillation methods, in which distillation is carried to (*a*) the overpoint of the new oil, (*b*) some definite vapor temperature, (*c*) some definite oil temperature, (*d*) the point where some property of the residue is the same as that for the new oil, or (*e*) the point of most rapid rate of change in the properties of the distillate

(5) Steam distillation methods, in which the charge is kept at some definite temperature and distillation is continued until either a definite quantity of steam has been condensed or no more diluent is brought over

[1] Bureau of Standards, City of Washington.

(6) Loss by evaporation under definite conditions

(7) Analytical distillations, such as repeated fractional distillations

(8) Vacuum distillation to (*a*) the overpoint of the new oil, (*b*) some definite temperature, (*c*) some definite oil temperature, (*d*) the point where some property of the residue is the same as that for the new oil, (*e*) the point of most rapid rate of change in the properties of the distillate, or (*f*) the point where the distillate coming over is oil, and the location from the distillation data on the curve is plotted from these data of the point, and the corresponding value of distillate, which best represents the transition from diluent to oil

Objections to Various Methods

Obviously, a method that involves a knowledge of the properties of the original new oil is not of general application. The question of the proper diluent to use in making up diluted mixtures for comparison is hard to decide and the assumption that the oil has not changed in use except by the addition of fuel diluent is not valid.

Use of the viscosity method (1) is subject to these limitations, so that only approximate accuracy can be expected. The method requires no apparatus or processes foreign to the ordinary oil-laboratory and, when only a few types of oil are dealt with, so that the work of establishing dilution-viscosity curves is not disproportionate, the method has the advantage of simplicity, especially as viscosities of the used oil are of interest of themselves. However, because of the tendency of oils to increase in viscosity when not subjected to dilution and because of the change in nature of the diluent with changes in fuel, carburetion, or operating conditions, considerable leeway must be allowed in the interpretation of results.

Specific-gravity methods (2) are open to about the same objections as the viscosity methods and, in addition, the specific-gravity range is so narrow as to make the method unattractive.

Flash-points (3) are dependent not only on the amount but also largely upon the overpoint of the diluent, which may change considerably with a change in operating conditions. Moreover, flash-point determinations are not subject to very great precision.

It should be noted that the foregoing three methods may give altogether false ideas of accuracy if tests are made on artificial mixtures of oils and diluents, as the uncertainties lie largely in lack of knowledge as to the exact nature of the oil and diluent components of the used oils.

Atmospheric Distillation Subject to Error

Atmospheric distillation methods (4) are in general subject to error due to possible decomposition of the oil into lighter compounds during distillation. This cracking is an inherent property of some oils and may occur at temperatures below those necessary to drive off all of the diluent. The error due to this cause is not, however, likely to amount to more than 2 per cent unless the rate of distillation is very slow. Rapid distillations are further desirable on account of the shorter time required for a determination.

Distillation to the overpoint of the new oil requires a knowledge of this overpoint. In addition, the assumption that distillation to this temperature will bring off all of the diluent and none of the oil is hardly valid. Duplicate runs do not check well unless distillation conditions are controlled accurately.

Distillation to some definite vapor-temperature obviously will not give the same degree of accuracy over a wide range of oils and fuels. The choice of temperature is necessarily arbitrary and that which is best suited to one oil, diluent and set of distillation conditions, would not necessarily be the test for another oil or diluent. The method does, however, have the advantage of simplicity and distillations to a well-chosen temperature under definite conditions should yield concordant, if not accurate, results.

Distillation to a definite oil temperature has been found to yield results that are rather more reproducible than distillation to a definite vapor-temperature. Also, the temperature can be so chosen as to preclude cracking. This method, however, has little else to recommend it and data covering a very large variety of oils are not available.

Distillation to the point at which some property of the residue, such as specific gravity, viscosity or flash-point, is the same as that of the new oil is not of general application. Here again the assumption is made that the used oil is unchanged except for dilution.

Distillation to the point at which the properties of the distillate coming over are showing the greatest rate of change is a rational method in that, whatever may be the exact nature of the diluent and oil components of the mixture, their properties do not merge uniformly one into the other as distillation proceeds. This is obvious from the fact that the end-point of the fuel is ordinarily at least 50 deg. cent. (90 deg. fahr.) below the overpoint of the oil; usually the difference is much greater than this.

The property that is followed may be the temperature of the saturated vapor, specific gravity, or viscosity. Separation of the components of the vapor by fractionation in the vapor column is desirable in order that the change be abrupt. A thermometer in the vapor column will indicate the transition from diluent to oil by a rapid rise in temperature, or successive portions of the distillate may be collected and the specific-gravity change followed.

Separation of Distillate by Specific Gravity

A convenient method of separating the distillate into two portions having specific gravities less than and greater than a definite value consists in feeding the distillate from the condenser through a tube into the bottom of a graduate containing an alcohol-water solution of the desired specific gravity. The distillate will rise at first through the solution and float and finally, as distillation proceeds, the heavier distillate will sink. A solution of denatured alcohol and about 14 per cent of water having a specific gravity of 0.845 (36 American Petroleum Institute deg.) will separate the distillate from most used oils approximately into diluent and oil. Distillation to a definite specific gravity cannot, however, be depended upon to give true results under all conditions and will yield erroneous results for oils that crack during distillation.

To follow the rate of change of viscosity of the distillate, this may be fed from the condenser into the receiver through a funnel having a capillary section. If the rate of heating be adjusted so as to maintain a small head of distillate on the capillary, the increase of viscosity as the oil begins to distill causes this head to increase rapidly. The increase in the rate of distillation with constant heat-input, which is associated with the appearance of oil, tends to emphasize this effect. This increased rate also occurs when the oil begins to crack, so the accuracy of this method is affected only slightly

by cracking. The volume of distillation corresponding to the abrupt change in viscosity of the diluent is taken as the volume of diluent in the sample. (See Appendix for details of the test.)

Steam Distillation Methods Empirical

Steam distillation (5) is resorted to in order to prevent decomposition of the oil during the process of distilling off the diluent. The charge of used oil may be held at some definite temperature, say 150 deg. cent. (302 deg. fahr.), and steam passed through the charge and then condensed, whereupon the diluent separates from the condensed steam. This distillation may be continued until (*a*) a definite amount of steam has been condensed, or (*b*) no more diluent is being brought over.

The method is empirical in that the choice of temperature is arbitrary and the chosen temperature will not necessarily be the best for all cases. The process requires from 30 to 45 min. for completion.

Methods of measuring the percentage of dilution from the loss in weight by evaporation from a definite sample under definite conditions (6) are also empirical as regards the choice of conditions and these conditions, especially ventilation, may be difficult to control exactly. Heating for 1 hr. at 200 deg. cent. (392 deg. fahr.) in a draft of air should remove most of the diluent, provided the exposed surface of the sample is not too small.

The most exact method of measuring the percentage of dilution is by a careful analytical distillation (7) that may involve an initial distillation under vacuum or with steam to remove the diluent together with the lighter components of the oil, followed by one or more fractional distillations on this diluent in which the diluent is separated completely from the oil. Analytical distillations are tedious and time-consuming and require the use of rather large samples of used oils, 500 cc. (30.51 cu. in.).

Distillation under reduced pressure (8) permits separation of the diluent without decomposition of the oil and the results are free from error due to this factor. The criteria listed under vacuum distillations will not be discussed, as they have been considered under atmospheric distillations. However, if a temperature criterion is used, care must be taken that the distillations are carried out under a definite specified pressure.

Method That Combines Speed with Accuracy

A method that seems to combine speed with good accuracy and reproducibility is the vacuum distillation transition method now used at the Bureau of Standards and described in greater detail in the appendix hereto. This method consists in the distillation of a charge of 100 cc. (6.10 cu. in.) of the used oil in a 250-cc. (15.25-cu. in.) distilling flask under a pressure low enough to preclude cracking of the oil. An absolute pressure of about 4 cm. (1.575 in.) of mercury seems to be sufficiently low for this purpose. This vacuum is easily obtained with the small, ⅛-hp. gear pumps now in rather general use.

The vapor column is filled with coarse steel wool to promote fractionation and a mercury thermometer is used to indicate the vapor temperature at the top of the column. An electric heater supplies heat to the flask at a constant rate and the distillation is carried on, taking temperature readings for each 1 cc. (0.0610 cu. in.) of distillate and for each ½ cc. (0.0305 cu. in.) over the transition region, until the distillate coming over appears to be oil.

Temperature-volume readings are plotted as a distillation curve and a straight line is drawn through the region of rapid temperature rise. The volume of distillate corresponding to the point at which the curve departs from this straight line is taken as the percentage of fuel diluent in the sample. The results may also be approximated from the distillation data without plotting.

Capillary Funnel Method Simple and Approximate

This is proposed as a simple approximate method for use when accuracy to within 2 cc. (0.122 cu. in.) is adequate. The apparatus consists of the following, as shown in Fig. 1: 350-watt electric heater or Bunsen burner, 250-cc. (15.25-cu. in.) distillation flask, condenser, 5 grams (0.1607 oz.) of No. 3 steel wool, cork, 100-cc. (6.10-cu. in.) graduate and a capillary funnel.

The procedure is to measure 100 cc. (6.10 cu. in.) of the oil to be tested into the distillation flask and place the column of steel wool, formed into a cylinder about 6 in. long, in the neck of the flask. Place the cork in the flask and support the latter on the heater or over the burner. Connect the condenser, which may be a 26-in. length of copper tubing of ⅜-in. outside diameter with a No. 20-gage wall, a short water-jacketed copper tube, or a conventional laboratory condenser. Place the graduate and the capillary funnel to receive the distillate.

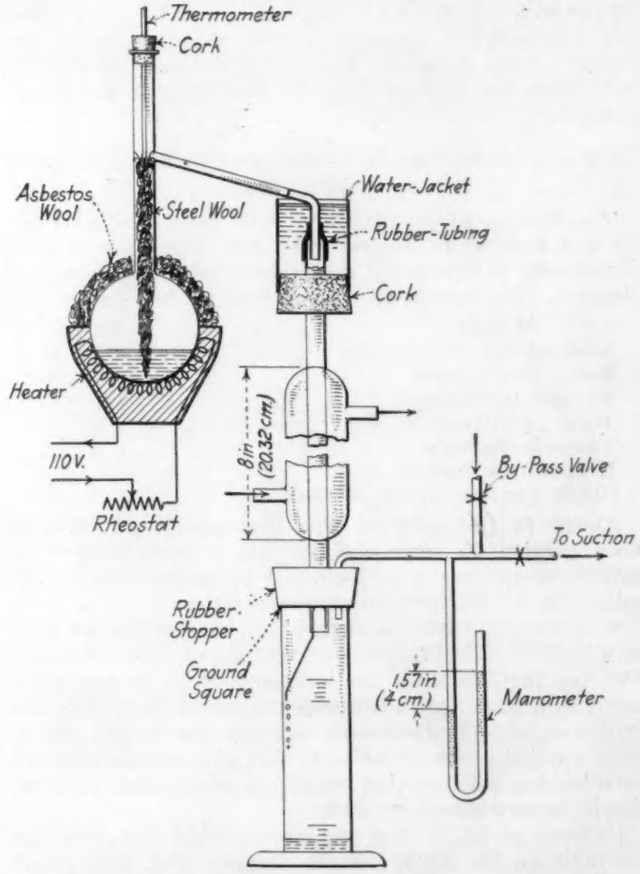


Fig. 1—Apparatus Used in Capillary-Funnel Method
A Distillation Flask at the Upper Right Containing a Charge of Oil Is Heated over a Bunsen Burner or an Electric Heater and the Vapor Passes Up through Steel Wool and Out through a Tube on the Right of the Neck of the Flask. It Is Condensed in Its Passage Down through a Water-Jacket and Drops into a Funnel Set in a Graduate Below. The Funnel Has a Capillary Tube in Which a Rapid Rise in the Head of the Distillate Indicates That Oil Is Beginning To Come Over. This Marks the End of Distillation and the Volume of Distillate in the Graduate Is Taken as the Percentage of Fuel Diluent in the Charge. Detail Drawings at the Right Give Dimensions of the Funnel and Flask and Show the Arrangement When an Electric Heater Is Used

If a gas burner is used, heat rapidly to the overpoint and then adjust the heat to maintain a head of about ½ in. of distillate on the capillary. Rapid increase in the head on the capillary as oil begins to come over is taken as the end of the distillation and the corresponding volume of distillate is taken as the percentage of fuel diluent in the charge. The color of the distillate and its apparent viscosity as it goes into the graduate are corroborative evidence of the end of the test. The time required is from 8 to 10 min.

The initial rate of distillation may be very great, if the oil contains much diluent, but it can be brought under control easily before the critical point has been reached. The appearance of oil is usually preceded by a marked decrease in the rate of distillation. When this occurs the heat should be increased gradually, because the transition is less marked if the head on the capillary becomes too small. An electric heater that fits the bottom of the flask will, with an input of about 350 watts, carry the distillation through without adjustment. Distillation may be started with the heater either hot or cold.

The dimensions of the capillary funnel are not critical. Those shown require a distillation rate of about 4 cc. (0.244 cu. in.) per min.

This method is only approximate and the results should be regarded as having a possible error of from 2 to 3 cc. (0.122 to 0.183 cu. in.). In general, results are slightly low, although this depends to some extent upon the operator. Very light oils tend to give lower results for percentage of dilution than do the medium and heavy grades.

Choice of Standard Methods Should Be Considered Carefully

The Bureau of Standards recently sent a circular letter to a number of laboratories requesting data relative to methods in use in the determination of percentage of dilution. The results are summarized as follows:

Method	Per Cent
Atmospheric Distillations	60
Steam Distillations	11
Vaccum Distillations	11
Total Distillation Methods	82
Viscosity Methods	13
Evaporation Methods	5
Other than Distillation Methods	18

About 75 per cent of the atmospheric distillations were carried to some definite vapor temperature, although there was practically no agreement as to the suitability of any particular temperature.

It is evident from the foregoing that various methods may be used to indicate the percentage of diluent in used oils. In fact, so many methods appear to possess some merit and, upon test with prepared mixtures of oils and naphthas, seem to yield very accurate results but which, when applied to used crankcase oils, give results that are considerably in error, that the choice of standard methods should be considered carefully.

Unfortunately, it does not appear that the precision desirable in the study of the factors that may affect dilution can be secured by the simple apparatus and in the short time of test that seem desirable for a method that will be attractive for very general use. An approximate method, if simple, would be of use to give data on which advice regarding crankcase service could be based. Dilution data would doubtless also be of some value in indicating desirable changes in operating conditions or the necessity for repairs to the engine. The methods described in the appendix are suggested as suitable for exact and for approximate use respectively.

APPENDIX

The Vacuum Distillation Transition Method for Measurement of Crankcase Dilution

This method of measuring the percentage of fuel diluent in a sample of used crankcase lubricating oil is based on the fact that, although we do not in general have an exact knowledge of the specific nature of the diluent and the oil components of the sample to be tested, we can reasonably assume that there is an abrupt change in the properties of the hydrocarbon compounds as we proceed from the diluent to the oil.

Distillation affords a convenient method of separating compounds of increasing molecular weight from the sample progressively and the temperature of the saturated vapor may be taken as an indication of the composition of the material that is passing the thermometer bulb at any stage of the distillation. If a charge of used oil is distilled under the proper conditions and a curve is plotted of the vapor temperatures against the volume of distillate, the transition from fuel diluent to oil will be indicated by a more or less abrupt rise in vapor temperature, as shown in Fig. 2.

Experiment has indicated that the transition point x, where the curve departs to the right from a straight line a-b drawn through the straight portion of the curve in the transition region, best indicates the volume of fuel diluent in the charge. The rational basis for the choice of this point is indicated by the forms of the distillation curves for the fuel diluent and for the lubricating oil.

Required Conditions and How to Get Them

The essential conditions of distillation and means for realizing these conditions are as follows:

(1) A constant rate of heat supply to the charge throughout the distillation. This may be secured by the use of an electric heater with constant input, and an insulated distillation flask

(2) A distillation pressure low enough to preclude cracking or decomposition of the oil before the diluent is distilled off. A pressure of 4 cm. (1.575 in.) of mercury seems to be suitable for most oils. This exact pressure need not be realized nor controlled accurately, as a difference or a slow drift of a few millimeters during a run is not serious. The pressure may be obtained by the small gear-pumps driven by ⅛-hp. motors now available, or by other convenient means

(3) At least a moderate degree of fractionation of the vapor is desirable. The necessity for fractionation increases as the boiling-points of the fuel and the oil components approach each other, but it seems that fractionation secured by use of the insulated flask with steel wool in the vapor column as described later is adequate for present needs

(4) A sufficient number of precise readings of vapor-temperatures and corresponding volumes of distillate must be taken to permit the drawing of a *smooth* curve through the transition region. Readings should be taken for each 1 cc. (0.061 cu. in.) of distillate, with additional readings for each ½ cc. (0.0305 cu. in.) in the transition region, and the curve drawn to a scale sufficiently large to permit accurate location of the transition point

Simple Apparatus and Its Arrangement

The apparatus used at the bureau is assembled as shown in Fig. 3. The distillation flask used is that com-

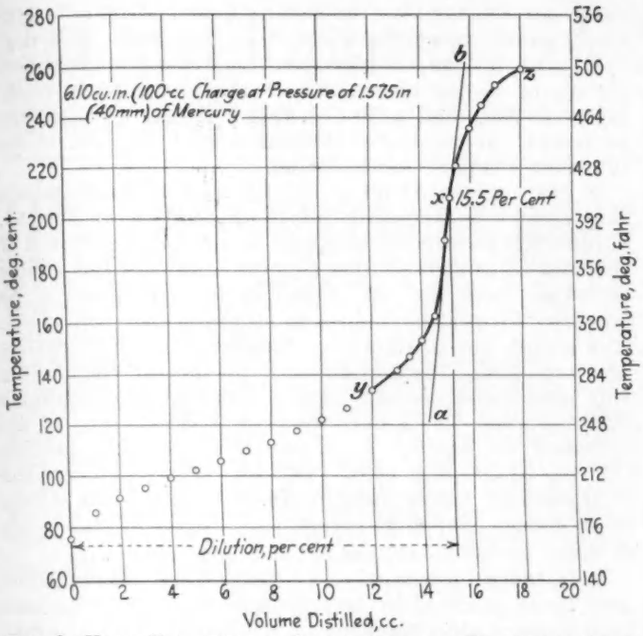


FIG. 2—VAPOR-TEMPERATURE CURVE SHOWING TRANSITION STAGE FROM DILUENT TO OIL

The Abrupt Rise in Temperature from y to z Shows the Transition Region. Where the Line a-b, Drawn through the Straight Portion of the Curve, Intersects the Vertical at x Indicates the Point at Which Diluent Ceases To Pass and Oil Begins To Come Over and the Point at Which the Percentage of the Volume of Distillate to the Original Charge Is To Be Ascertained

monly listed as a 250-cc. (15.25-cu. in.) Engler distillation flask. The stock flask is supplied with a straight side-tube 6 in. long. For this work about 1½ in. of the end of this tube is bent vertically downward. A straight-tube condenser having an 8-in. water-jacket is used. A condenser temperature of 30 deg. cent. (86 deg. fahr.) is sufficiently low.

The receiver is a 50- or 100-cc. (3.05- or 6.10-cu. in.) graduated cylinder with the top edge ground off square below the lip. The heater is of the Bureau of Mines type, consisting of a heating element embedded in a refractory insulating material which conforms to the bottom of the distillation flask. An electrical input of about 150 watts is required but the heater may have any capacity greater than this, as a regulating rheostat may be desirable. Heaters in which the transfer of heat to the flask is due to convective circulation of air are not as satisfactory as those which fit the bottom of the flask closely.

The top of the flask is insulated up to the base of the neck by about ½ in. thickness of asbestos wool or its equivalent. About 5 grams (0.16075 oz.) of coarse, No. 3, steel wool formed into a cylinder 6½ in. long, is located in the flask, as shown in Fig. 3. This cylinder is recessed at the top for the thermometer bulb.

An American Society for Testing Materials low-range distillation thermometer graduated in centigrade or fahrenheit degrees, is mounted as shown in the axis of the neck of the flask, with the lower edge of the white enamel backing on a level with the lower edge of the vapor tube. The bulb fits into the recess and is in contact with the column of steel wool. This tends to steady the thermometer indications and prevents irregularities due to the collection of condensate on the bulb. The thermometer is fitted in a good cork that fits into the neck of the flask. A little glycerin serves to prevent leakage, which should not be permitted at this point as the presence of air tends to depress the vapor temperatures.

The vapor tube is joined to the condenser, which may be of glass or metal, by a short piece of rubber tubing surrounded by a water jacket movable along the axis of the condenser for convenience in assembling. The tip of the vapor tube is wet with glycerin to prevent sticking to the rubber joint.

The receiver is held by the suction against the rubber stopper mounted on the condenser tip. A tube connecting with a manometer, through a by-pass valve to the atmosphere, and to the source of suction, also passes through this stopper. These particular methods of securing the various joints and of controlling the pressure are suggested as being feasible with the use of ordinary laboratory materials. Other methods of reaching the same end are, of course, permissible.

THE METHOD OF OPERATION

The input to the heater, about 150 watts, is adjusted once for all so as to distill a 100-cc. (6.10-cu. in.) charge of water at the rate of about 2.5 cc. (0.1525 cu. in.) per min. under atmospheric pressure. All runs are started with the heater hot.

A 100-cc. (6.10-cu. in.) charge of the sample is placed in the flask, the steel wool and the thermometer adjusted, the flask placed on the heater, the connections to the condenser made, the pressure in the system brought immediately to the desired value, 4 cm. (1.575 in.) of mercury, and the insulation placed on the top of the flask. Care should be taken that the flask does not remain too long on the heater *before* the pressure is reduced to 4 cm. (1.575 in.) as otherwise foaming and carrying

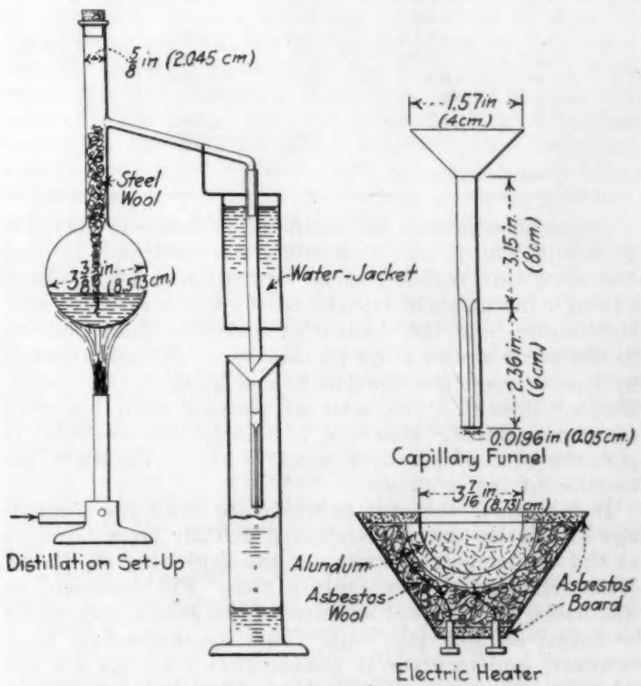


FIG. 3—APPARATUS USED IN THE VACUUM-DISTILLATION-TRANSITION METHOD

The Charge of Oil Is Heated in a Flask over an Electric Heater at the Right, Controlled by a Rheostat. Vapor Passes Up through Steel Wool in the Tube, in Which Is Inserted a Thermometer, and Out through the Tube on the Right to a Water-Jacket Condenser. The Condensate Drops into the Receiver Below. The Desired Vacuum in the System Is Created by Suction Applied to the Lateral Tube at the Lower Right, Opening into the Receiver and Connected with a Manometer and a By-Pass Valve. Temperature Readings Are Taken as Each 1 Cc. (0.061 Cu. In.) of Distillate Is Obtained until the Temperature Begins To Rise Rapidly, and Then at Each ½ Cc. (0.031 Cu. In) until the Distillate Coming Over Appears To Be Oil and the Rate of Temperature Rise Begins to Decrease. The Temperature Observations Are Then Tabulated as in Table 1 and a Curve Plotted as in Fig. 2

over of oil may result. An abrupt reduction in pressure during distillation may also result in foaming.

Readings of vapor temperature are taken at the first drop and at each succeeding cubic centimeter (0.061 cu. in.) of distillate until the temperature begins to rise rapidly, when readings are taken at each ½ cc. (0.0305 cu. in.) or oftener, if desired. These readings are continued until the distillate coming over appears to be oil and the rate of temperature rise has begun to decrease. The decrease in the differences between successive temperature readings indicates that the transition point has been passed. The time interval between the volume and the temperature readings should be uniform and as short as practicable.

TABLE 1 — SAMPLE DATA SHEET FOR 100-CC. (6.10-CU. IN.) CHARGE DISTILLED AT A PRESSURE OF 4 CM. (1.575 IN.) OF MERCURY

Volume of Drop, Cc.	Volume of Drop, Cu. In.	Temperature, Deg. Cent.	Temperature, Deg. Fahr.	Difference, Deg. Fahr.
		76	169	
1.0	0.061	86	187	
2.0	0.122	91	196	
3.0	0.183	95	203	
4.0	0.244	99	210	
5.0	0.305	102	216	
6.0	0.366	106	223	
7.0	0.427	110	230	
8.0	0.488	113	236	
9.0	0.549	118	245	
10.0	0.610	122	252	
11.0	0.671	127	260	
12.0	0.732	134	273	
13.0	0.793	142	286	
13.5	0.824	147	295	9
14.0	0.854	153	307	12
14.5	0.885	163	325	18
15.0	0.915	192	378	53
15.5[a]	0.946	221	430	52[a]
16.0	0.977	236	457	27
16.5	1.007	245	473	16
17.0	1.038	253	488	15
18.0	1.099	259	498	

[a] Transition point.

These observations are tabulated in Table 1, plotted as shown in Fig. 2, and a smooth curve is drawn through the transition region *y-z*. A straight line *a-b* is drawn through the straight portion of the curve in the transition region and the volume of distillate corresponding to the point *x* where the oil section of the curve begins to depart from this straight line is taken as the percentage of diluent. The scale of plotting used has been found convenient. However, it is sometimes desirable to plot the section *y-z* to a larger scale to facilitate the location of the point *x*.

It is obvious that for approximate work the percentage of dilution may be evaluated directly from the data as the volume corresponding to the beginning of the decrease in rate of temperature rise. For instance, on this basis, the per cent dilution of the sample run would be taken as 15.5 per cent. This approximation may, however, lead to error if temperature readings are not taken at small-volume intervals or if the data are erratic.

AVOID AIR LEAKAGE AND REMOVE WATER

Overpoints, or first drop, lower than 65 deg. cent. (150 deg. fahr.) at 4-cm. (1.575-in.) pressure should be regarded with suspicion as possibly indicating appreciable air leakage into the vapor column. Used oils generally show overpoints of about 80 deg. cent. (176 deg. fahr.), except for samples resulting from abnormal conditions of engine operation. If the overpoint is really below 65 deg. cent. (150 deg. fahr.) it may be necessary to reduce the condenser temperature by the use of ice to secure complete condensation.

If the sample of oil to be distilled contains water, this should be removed before distillation is started. Ordinarily, sufficiently complete separation is secured if the used oil is allowed to settle over night and the sample is drawn from the top of the vessel. As there is no tendency for diluent and oil to separate, this will give a true sample for distillation. Another expedient consists in starting the distillation with the heater cold. This will sometimes permit distillation with considerable water present. As a final resort, the sample may be dehydrated by heating in a closed bomb with calcium chloride to 200 deg. cent. (392 deg. fahr.) as described in Bureau of Mines Bulletin No. 207. This will seldom be necessary, however, except in the case of heavy oils or when persistent emulsions have been formed.

Data taken on a number of lubricating oils, together with those reported by several outside laboratories that have cooperated in checking up the method, indicate that results accurate to within ½ cc. (0.0305 cu. in.) may be expected. The agreement between different runs on the same sample in a single laboratory is decidedly better than this.

The diluent used in making up artificial samples correspond to that ordinarily present in used oils. The 20-per cent residue from commercial gasoline after 80 per cent has been distilled off in an Engler distillation flash approximates this diluent fairly closely.

ADVANTAGES OF THE METHOD

The method described has the following advantages:

(1) A knowledge of the oil or fuel used in the engine from which the used sample is drawn is not necessary

(2) No cracking or decomposition of the oil occurs during the test

(3) The time required is short, 15 min.

(4) The evaluation of the result is not influenced appreciably by personal judgment

(5) Measurements of actual vapor-temperature are not essential. The requirement is that the indicated temperatures in a given test shall be self-consistent, as we are interested in the changes in temperature during the run and not in the true temperatures

(6) The accuracy of the test is not affected by moderate changes in procedure. For instance, the rate of distillation or the pressure at which distillation is carried on may be changed by ± 50 per cent of the specified values without appreciable effect upon the results

(7) The test method is rational rather than empirical and reliable results are obtainable over a wider range of oils and diluents than could be expected from an empirical method

(8) The accuracy is adequate for all present needs

This method is to be proposed as a standard method for the determination of the percentage of fuel diluent in used crankcase oils.

Development in Naval Aeronautics

By Com. H. C. Richardson[1], U. S. N.

Aeronautic Meeting Paper

THE discussion following the presentation of this paper at the Aeronautic Meeting of the Society that was held at Dayton, Ohio, on Oct. 2, 1924, was entirely oral, no written contributions having been received. In accordance with the usual practice, the stenographic report of these remarks has been submitted to the various speakers for their approval and to the author for any additional comment that he cares to make. The corrected discussion, as received, is printed below. An abstract of the paper precedes the discussion so that those of the members who did not read the paper when it was printed in the November, 1924, issue of The Journal can gather some knowledge of the subjects covered by reading the abstract if they do not wish to read the complete text.

ABSTRACT

PRINCIPAL developments along the lines of the HS, H-16 and F-5-L types of airplane, which were used during the war for convoy work, submarine patrol and scouting, are represented by present types PN-7, equipped with Wright T-2 engines, and PN-8, having Wright T-3 engines, a metal hull and metal tail-surfaces. Brief statements about their construction and performance are made and the subject of metal floats for airplanes is discussed. "Training," scouting and other types of airplane are mentioned, and outlines given of their characteristics and performance.

Launching seaplanes from a catapult is described, some details of the development of the apparatus being given, and reference is made to a late development in which the catapult is actuated by the explosion of a powder charge instead of being operated by compressed air. Aircraft engine, propeller and accessory developments, seagoing aircraft-carriers and lighter-than-air craft are treated also, and numerous illustrations are presented.

THE DISCUSSION

Chairman H. M. Crane:—From what Commander Richardson has said, I think you will realize that naval aviation is a problem of coordination and not one of substitution; it has faced the Navy all along, it is facing the Navy today. So long as we have the present colonial policy, the Navy must operate in distant lands and it must keep communication with the Philippines open in times of emergency.

We are fortunate in having with us a visitor from Great Britain, who is the editor of one of the important aviation papers in that country; he has lived with aviation over there from the start and, especially through the war, has seen the dual system in which the Army and the Navy were separate, and has now seen the combined air-service force. I say this to give you an idea of his knowledge of the whole subject of military and of civilian aviation. I present Mr. C. G. Grey.

C. G. Grey[2]:—The flying boat is essentially an American invention. The first flying boat was turned out by Glenn Curtiss, and the first large flying boat that was attempted was the joint effort of Mr. Curtiss and Commander Porte, as he was then, of the British Navy. It was a flying boat built for John Wanamaker with the idea of flying the Atlantic before the war. Commander Richardson said that the first large flying boat he illustrated was built to British designs, but those designs were only a modification of that first large American flying boat. I do not know to what size your flying boats have now developed but, in England, we have gone fairly far with increasing size. The latest one that we have had in the air has four 700-hp. Rolls-Royce engines, a rather large lump to get into the air; but it does not fly badly, considering that it was designed during the war and has been "monkeyed with" ever since. It was laid up for a year or two, and it actually made its first flight only a few months ago.

Commander Richardson spoke about duralumin hulls of boats. That subject interests all aeronautical engineers who have anything to do with sea work. We have had a belief in England and I think it is general in most of Europe, that duralumin could not be trusted within smelling distance of seawater; but, apparently, you in the United States have disproved that entirely. We have heard nothing about your Navy's flights with flying boats having hulls of duralumin, but we have heard something about what the Aeromarine Plane & Motor Co. of Keyport, N. J., did. That company did pioneer work in that direction. I am told by Paul G. Zimmerman, one of the active members of that firm, that he hopes to go on with the construction. I hope something fresh may develop from that, because undoubtedly the metal hull and metal float for seaplanes constitute the solution of that very great objection, water-logged wood. Incidentally, the metal construction of airplanes is coming to the fore in Europe. The Germans have done good work in that direction.

We have done a fair amount of development work in England, but it is very largely in the direction of steel lattice-work. My personal opinion is that we have made too many attempts to build steel aircraft on the lines of wooden airplanes; that is, we have tried to replace all the wooden members by steel structures of very much the same form, instead of branching out on radical alterations in the way they have done in Germany with duralumin. Some people have an idea that the metal airplane of the future will get away from imitating a bird with its skeleton inside a covering, and will imitate the lobster by having the skeleton outside and making that do all the work.

Another phase of this method has something to recommend it. For instance, in the case of a very light metal-covered wing, a heavy-booted mechanic is likely to make dents in it while trampling about; but, when large machines are made, such as weight-lifting bombers, the wing structure will take local stresses as well as the actual loads it has to carry. Commander Richardson smiles at that, but we may come to it. If a hull can be made that way, perhaps a wing can be made that way also.

Commander Richardson emphasized the fact that, for the lighter seaplanes, you have settled practically on the central float with two wing-tip floats instead of using twin pontoon-floats such as we use in England altogether. I can say definitely that we have not a single central-

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float machine in use in England. Will Commander Richardson state the reason that the Navy has found the central float better?

COMMANDER H. C. RICHARDSON:—Our experience, including that of having had the F-5s go down to the West Indies, shows that central floats have encountered all sorts of storms and bad weather and that the central-float machine has proved best, because the principal weights are carried directly to the hull itself and the hull reinforces the fuselage. Of course, in boats, both the fuselage and the hull are combined but, in the central-float plan, we have the fuselage, which is a complete structure, and the float itself, which is a complete structure, tied together by struts and wire that practically make those two a complete structure. The experience which we have just had with our seaplanes in the Arctic regions shows that the little UO-1 seaplane equipped with a central float is entirely capable of standing just as bad weather as the large flying seaplane of the F-5 type, and we also know that the twin-float types, when they get into a bad seaway, are subjected to very severe racking stresses. With a central float, the load is over the pier; with the twin-float, it is in the middle of the span.

MR. GREY:—We have some hundreds of twin-float seaplanes in use in the English Channel and in the Mediterranean, and they seem to do their work very well. It would be rather interesting to know, for competitions when you have to build really high-speed planes that must sit down on the water very hard, like your machines that came over to lift the Schneider Trophy last year, why all your machines have twin pontoons.

Like the United States Navy, we have been doing a great amount of experimental work with the amphibian type of seaplane. There again we have had the best results, I think, from twin-float machines with a wheel inside each float. For many years people tried to evolve seaplane floats that had a hole cut in the bottom through which a wheel protruded so that they could be run along on deck; or, on the beach, to put them into the water. It was fairly easy to make them so that they could be flown off a beach or a deck and alight safely on the water, but the trouble was that they could never be got off the water. Some curious dragging action is exerted even by a small wheel, which entirely prevented them from getting off and it is only within the last few months that C. R. Fairey, of the Fairey Aviation Co., has produced a float through which a wheel can be put. The wheel is absolutely fixed; it is not hauled up or down as in the old amphibians. We have at our National Laboratory the Froude Tank in which experiments in ship forms and the like are carried out. This float was tested there and, after breaking up most of the testing apparatus, a successful type was produced.

I noticed that Commander Richardson pictured an amphibian as a single-engine flying-boat. The single-engine boat has done much good work and it seems to be popular, more especially since our unfortunate attempt to fly around the world. The actual failure of the English aviator, McLaren, at the finish was simply due to getting into a fog and coming down in an impossible sea. It was not any inherent fault of the boat or engine.

Commander Richardson mentioned that these new seaplanes of yours are being fitted with air-cooled engines instead of water-cooled. That question seems to be occupying almost everybody's mind who is concerned in aviation at present. I notice that the Curtiss Co. has just turned out a radial air-cooled engine after the splendid success of the D-12. We have experimented extensively with air-cooled engines. We have the 400-hp. Bristol-Jupiter engine with 9 cylinders in one row, air-cooled; and the Armstrong-Siddeley engine, with 14 cylinders in two rows. But no one seems to have decided yet whether the air-cooled engine definitely has any advantage over the water-cooled engine. Still less is there any decision as to whether the two-row engine has any advantage over the single-row engine.

Recently, I was in one of our big aircraft works and saw two of our latest type machines; one having 9 cylinders in a single row and one having 14 cylinders in two rows. The 14 cylinders "staggered" between the two rows. I asked the managing director of the firm which of the two engines he really preferred and he said: "Apparently, it is entirely a matter of taste whether you prefer a chrysanthemum or a sunflower." He thought the two-row engine with the valve rockers sticking out looked like a chrysanthemum, and it did.

Another point of aircraft design which is creating great interest is that of wing flaps. I do not know whether any American machines are actually being built that have wings in which the whole of the trailing edge aft of the rear spar can be pulled down to increase the lift. Recently, at Port Washington, N. Y., I saw a machine that is being built by Mr. Kirkham, formerly of the Curtiss Company, for Mr. Vanderbilt. It is built entirely of metal and has corrugations all over it. It is an interesting machine. He has used flap trailing edges and seems to think they are working rather well.

Your catapult launching-gear on warships is of very great interest. We have never tried it at all seriously in the British Navy, and I have never been able to discover why. I do not know whether it is absolutely the right thing or not. It seems to me that catapults have one great advantage; it is that, once the machine is let go on a catapult, it goes clear of the ship. If the engine goes dead just as the machine is going over the side, the pilot has a chance of getting down into the water. We have lost several very good pilots and machines because of engines that did not absolutely go dead but that just lost power when they were getting off the deck. The result was the machine went off the bow of the ship and was not exactly rammed but was squashed down by the ship. A catapult seems to provide a singularly uniform way of launching.

Merely speaking as a visitor, this aviation meeting certainly presents a bigger showing than anything similar that has been held in Europe to my knowledge. It is particularly interesting because it shows the amount of real hard work which is being done on aviation in the United States. Nothing in England, and certainly nowhere else in Europe, approaches the independent flying done by flyers who have come here from all parts of America. It shows that an immense amount of keenness exists about aviation. The machines are mostly "disposal" war stock. Not only is it an excellent way of using war stock, but it is spreading the gospel of aviation in a way that it is not being spread anywhere else. We have, in England, a few people who run what are known as "joy-ride shows," but the people who have flown here all seem to have their own distinct engineering ideas. Each man has his own notion of what an airplane ought to be like and how it ought to be put together, and I think most of the machines in the aviation field here are pretty safe to fly. They might not pass the most rigid Royal Air Force inspection, but the fact that they are here shows that they have not killed anybody. In a way, the aviators I refer to are doing serious engineering. It is not like designing an aircraft and putting it through a proper factory course of production,

but it shows the mechanical ability and the keenness concerning aviation in the Country. From that, civil aviation will develop.

CHAIRMAN CRANE:—In connection with Commander Richardson's paper, the extensive field that is open to us industrially if all-metal airplane-construction becomes a serious factor comes to my mind. He spoke of certain floats that were being made by Brewster. I happen to have been shown those floats at different times in the course of their construction, and it is interesting to know that the man who built the float really knows little about the design of airplanes. He is just the superintendent of the plant and has control of an excellent body of metal workers. This indicates that, if we ever get to using metal floats and demand them in considerable quantity, we have in this Country the ability to make them in great quantities of the very highest quality without educating the personnel to do it. That certainly will be of great advantage in case of sudden national emergency.

QUESTION:—What is the propelling power in a catapult?

COMMANDER RICHARDSON:—To date, compressed air has been used in this Country. I believe the English used hydraulic power in some catapults. We use a compressed-air engine that has a multiplied purchase; that is, the piston drags a cross-head. Several sheaves are mounted on that cross-head and, in addition, there is a set of standing sheaves. The purchase passes around so that the motion of the cross-head is about one-seventh the motion of the car. We get a multiplied effect in that way. Also, we use auxiliary air-flask action; the flasks are charged at a certain initial pressure, depending on the weight of the airplane we are to launch and the speed we want it to have at the end of the catapult run. That speed can be determined ahead of time, and we charge the auxiliary air-flasks accordingly. In the latest design, an explosion of powder produces the power.

QUESTION:—What is the United States Navy's method of launching seaplanes from ocean-going submarines?

COMMANDER RICHARDSON:—So far as I know, to date, it is to float them off; we have not as yet done anything else in that respect. They are assembled on the deck and are floated off; or, they can be run overboard as if run off a beach. The submarine can be partly inclined at the time, and inclined the same way when the machine returns in just the same manner as for an inclined sea beach. In such cases, of course, the planes are float planes. We have made that experiment with only two types of plane.

RALPH H. UPSON[3]:—What is the comparison between the advantages and functions of the regular seaplane and those of the type which has a body separate from the float?

COMMANDER RICHARDSON:—The advantages are not particularly clear. For a large-size type it is of considerable advantage to put everything right into the hull itself and avoid a duplication of structures. But for a small plane, you are practically forced to put the engine a certain distance above the level of buoyancy that is provided for flotation and it is of advantage to place the fuselage behind that. In that case, you will come to an independent-float type. We have an amphibian with which you are familiar that is a combination of those two. It is a boat-float type in which the float itself is directly connected to the fuselage in the new Loening amphibian boat. In that case you have the advantage of having a tractor type of boat, and the propeller is protected by the float itself. The engine is kept pretty low, but the fuselage is directly behind the engine in that case. For large sizes, it is of advantage to utilize the hull itself.

QUESTION:—Has it been found that the best contour for the hull of a seaplane is anything like the best contour for an airplane, and the same for the streamline; in fact, are there any relationships between those two contours?

COMMANDER RICHARDSON:—No; the seaplane boat, to give satisfactory results, is dependent entirely on seaplane properties. To accomplish that we are practically forced to the V-bottom type to eliminate shock and, to get the best results so far as resistance is concerned in getting off the water, we are nearly forced to use the step. That gives us a form of bottom that has not the best streamline form. If we consider the best streamline form and give the float the form of a dirigible, for instance, which is an excellent streamline form, we could not get it off the water if we practically filled it full of dynamite, because that form of hull would produce so much suction in driving at high velocity over the water that it would swamp itself. We have tried such a form in a model-basin test. We provide that, at each particular speed, the amount of weight that rests on the water shall be the same as would be the case if the wings were supporting the plane; that is, at the get-away speed, the wings are carrying all the load. At zero speed, all the load is carried by displacement. In between those two conditions, the weight is carried by the wings according to the speed, and the rest of the weight is carried by the water.

We tried a float that had curved ends, which had, not the best, but a good streamline form, under conditions where all the load was being carried by the wing; the bottom of the float was just in contact with the surface. We started it off and, before it reached get-away-speed, it was down with its deck flush with the water. We have since made another model test on which we tried to install blades to lift the hull and bring it out of the water. We had this curved type of hull and, for other reasons, we knew we would have to overcome that suction. When the needed size of the blade was calculated, we found the blades had to lift the whole weight of the plane itself to overcome the suction of that form; so, the streamline form itself is not directly adaptable.

On the other hand, with a cylindrical deck and a reasonable form of stern of the float such as we use in our pontoons, we have found that the resistance is not very much higher than it would be for a good streamline form. For instance, that very awkward hull we had on the NC type had a resistance which we did not believe possible until we had run it again and again and checked it up. The resistance was about one-ninth of the resistance of its projected area, and if we had modeled that on a streamline form for its proportion, we could not have bettered that figure very much. We did not suffer much from changing the bottom form to suit water conditions.

GEORG H. MADELUNG[4]:—Nobody can sufficiently appreciate the great contribution of the United States Navy in the development of metal aircraft, especially of all-metal pontoons in duralumin construction. There are yet people, for instance in England, who shun dura-

[3] M.S.A.E.—Chief engineer, Aircraft Development Corporation, Detroit.

[4] M.S.A.E.—Managing engineer, Junkers Corporation of America, New York City.

lumin. Of course we had our troubles, such as cracks, corrosion and the like, when we started using it, but we had trouble with steel too, and I must say we had more trouble with steel than we ever had with duralumin. When steel is brazed or welded difficulties are bound to come up, even with the best workmanship and in the best organized shops. On the other hand the difficulties with duralumin could always be traced back to violations of the elementary rules of its treatment.

For instance, immediately after tempering duralumin is soft and can be cold-worked pretty much without harm. If this is overdone, however, the material becomes brittle and corrodible. We were up against this problem when we first started using corrugated duralumin sheets, because the primitive corrugating tools, which we used during the experimental stage of production, overstressed the sheet metal. Since then we have improved our equipment and are using a special, home-built brake which corrugates the sheet metal without distorting it. In this way we have eliminated the brittleness and corrodibility, which was not a fault of the material but of an inadequate manufacturing process.

As far as durability is concerned, I must say that our expectation has been completely justified by our experience during the last 8 years. I may mention in this connection that the Junkers airplane on which I flew from Detroit to Dayton, with seven people on board, was built either in 1919 or early in 1920. Mr. Stinson has flown it regularly ever since he bought it second-hand shortly after his endurance record in 1921. He kept it in the open air all the time, day and night, summer and winter, season after season, in snow, ice, rain and sunshine, and it still flies as it did when it was new, at the same speed, with the same flying properties. Mr. Stinson told me that with this ship he has flown between 3500 and 4000 hr. This would mean that the old plane, since he bought it second-hand, has covered something like 300,000 miles and is not yet ready for the scrap-heap. A motor truck is usually scrapped after 60,000 miles' run, a locomotive after 700,000 miles, after being overhauled over and over again. This old airplane's run is more like that of a locomotive than that of a motor truck. You see why we are optimists in the matter of durability.

Regarding the matter of a single float versus twin floats, I was interested to hear that this is more a matter of structural strength than a matter of service. I understand from Commander Richardson's paper that in the experience of the United States Navy single-float planes are able to weather a rough sea that would break up any twin-float plane. Does this experience justify the conclusion of an inherent weakness of the twin-float system?

Suppose that a twin-float and a single-float plane are both designed and built according to the same general assumptions as to load condition, load factor, load distribution, and the like. If one breaks up under conditions where the other stands up, something must be wrong with the assumptions. The failure of the twin-float system in a rocking sea shows that one or more of its structural members were not properly designed to meet this peculiar situation. This does not mean, however, that the two systems could not be designed so as to be equally strong under any equal conditions.

I believe that unsymmetric load-distribution is the main cause of the failure of twin-float systems; for instance, one load at the top of the left float and another load at the stern of the right float. Unsymmetric load-distribution of this sort cannot occur with the single-float type, and can be neglected without harm. In the twin-float type, however, it does occur and if it is not reckoned with, breaks must be expected.

I do not believe that structural weakness is an inherent quality of the twin-float system. I believe it will be possible to analyze the peculiar load conditions which occur on twin-float aircraft in heavy sea. In this way we will arrive at rational warranted assumptions and, when these are used in stress analysis, I am convinced that the peculiar weakness will disappear which is now found in some aircraft of this type. Incidentally, I may mention here that all Junkers seaplanes are of the twin-float type and that we have never seen any necessity to change in favor of the single-float type. Of course, in these planes, the conditions are unusually favorable. The unsymmetrical loads are carried without difficulty by the underslung wing, to which the floats are attached. The twin-float system has many advantages, such as absence of wing-tip floats, lateral stability, and the like. If the weakness experienced can be overcome by improved knowledge, it should not be permitted to discourage the use of a system good in principle.

COMMANDER RICHARDSON:—I will not try to say whether Dr. Madelung is right or wrong, but will give my opinion as to the effect of putting the strength into the structure that he says it must have, and with which I agree. The structure will become unnecessarily heavy over what it would be in case of a central float properly disposed, with a very moderate tip float. Consider the case of the F-5 type and the case of the NC, which you know about, a plane of 28,000-lb. displacement, and making those hulls split up into two hulls of the proper displacement. To get one-half the displacement in a float, you would have dimensions that would be in the proportion of 1 to $\sqrt{2}$ in linear proportions when compared with the originals. It would be found that this would not produce a very great reduction in dimensions. In trying to make two floats work evenly in a seaway you will have terrific twisting stresses come into play in proportion to their size. I think we have never built a transatlantic liner with twin hulls that was successful, and I think we never shall.

QUESTION:—What is the effect of the catapult on carburetion? Do you meet difficulties of that sort?

COMMANDER RICHARDSON:—We do have difficulty. There is something wrong about the design of the carbureter or the gasoline system under that horizontal acceleration of 2.5 g and its component 1.0 g vertically. Something happens to the gasoline. In certain cases, we have had the engine starve, or choke by getting too rich a mixture; we have not determined which it is, as yet. We are working hard to find the difficulty that does not always occur under the same degree of acceleration. We have had the difficulty more particularly with the air-cooled engine than we have had it with the water-cooled engine. It is probably a difference in the carbureter arrangement and must be taken care of. The carbureter is practically standing on its side for 1.5 sec. of impulse. One might think that, for 1.5 sec. the gasoline could be shut-off from the carbureter and that there should be enough gasoline to keep the engine running during that time; but, something prevents it, and we are studying the condition. The answer is not definite; that is where the hard part comes in. We will get one launching where there is no starving at all, the engine having the same number of revolutions per minute all the way down the run; and, in other cases, we have actually had the same engine cut-out entirely.

CHAIRMAN CRANE:—What is the situation today regarding the cost of metal-float construction? It is

unfortunate that, in a metal float, riveting has to be done to produce water-tightness as well as structural strength. That means driving many more rivets, and I understand that it is expensive.

COMMANDER RICHARDSON:—The present ratio between wood-float and metal-float construction-cost is about 9 to 70. It is not very encouraging but, when we get the type simplified by experience, with the aim in view of a structure that is practicable to assemble while still retaining the necessary structural strength, I think that we can reduce that discrepancy. I think not only that but, when we get into real quantity-production, the discrepancy will necessarily be reduced further. But we are not standardized. The ratio I am giving you is on a design of which we made different variations in the course of construction. One variation was the changing of the disposition of the metal; that is, the thickness of the metal. Also, there is a difference in the arrangement of other members. But the average cost would be about $7,000 for a metal float, whereas, we can buy a wooden float for the same purpose for about $900. That is pretty expensive, and it is not very encouraging to anybody who wants to start in the business; but changes are going to come and the situation will clear-up. The more heads we get to concentrate on the job, the faster it will clear-up.

CHAIRMAN CRANE:—What chance is there of controlling the welding on the job? You said that welding is not satisfactory at present. Can it be made satisfactory?

COMMANDER RICHARDSON:—We are not bothered much about the mere water-tightness of the weld but, if we do not heat-treat it, we get bad corrosion about 1 in. away from the weld. Apparently, the temperature that is used in welding produces a condition that makes the metal peculiarly susceptible to corrosion; but, after the weld has been heat-treated, that condition is removed. However, when we heat-treat a complicated structure, it warps like a piece of pie crust and has an unsatifactory streamline form.

W. H. BARLING[5]:—Taking the large sum of money that has been spent on the Shenandoah into consideration, what are the relative merits of lighter-than-air and heavier-than-air craft?

COMMANDER RICHARDSON:—The question is controversial; I cannot answer it.

CHAIRMAN CRANE:—What is the best thought now as to the size of planes for endurance flight only? About what size, in weight and in horsepower, would appear to be the best?

COMMANDER RICHARDSON:—At a rough estimate, probably the total weight should not be more than say 30,000 lb. I think it could be done economically on that. Using a larger size than that would not accomplish a very great increase in cruising radius; that is, just to carry fuel load to get there. To carry commercial loads would require a larger machine. It might be possible to use less than a 30,000-lb. total weight, depending upon the engine available and upon how many engines it is desirable to use.

QUESTION:—Was not the weight of each airplane on the round-the-world flight about 8000 lb.? That is far different from an airplane weight of 30,000 lb.

COMMANDER RICHARDSON:—But the machine of 30,000-lb. weight I refer to is traversing some 2000 miles in a single hop, and the round-the-world airplanes could not do that. I think they weigh about 8000 lb. each, with the maximum load.

J. H. HUNT[6]:—Mr. Barling has raised a question regarding the relative advantage of spending money on lighter-than-air craft or spending it on heavier-than-air craft; that is, an equal amount of money in the two cases. It seems to me that the real reason for developing both types is illustrated by Commander Richardson's statement of spending $7,000 for a new type of float when a float that would serve perfectly well can be bought for $900. In doing this, the Navy is looking to the future. We cannot determine the value of the lighter-than-air type of aircraft until we try it. It may be that we can see an immediate result with the heavier-than-air craft, a better result with a given amount of money, than we can with lighter-than-air craft; but, until we try it out, we cannot know. We seem now to be experiencing that process, and it is an expensive process.

Will Mr. Grey say something about the Handley-Page wing? We hear considerable about it.

CHAIRMAN CRANE:—Supplementing that question, I admit my own curiosity about that type of wing or any other similar variation from the straight head, permanently adjusted wing. Various proposals have been made for building an airplane that has a greater list when taking-off and greater head-resistance at landing, but having lessened resistance while in the air. So far as I can see, we are still clinging to the wing design we have at present, with the wing fixed permanently in position, and letting it go at that.

MR. GREY:—Regarding the Handley-Page wing, I think its chief trouble lies in the operating mechanism of the slat. The Handley-Page wing represents an attempt to make a wing rather like a Venetian blind. So far, it consists of an ordinary wing with a slat across the leading edge of each wing. This slat lies flat on the edge and forms part of each wing under normal circumstances, but can be brought forward and then produces a slot between the slats and the wings. The idea is that when the wing is at a very obtuse angle in the air, the slot can be opened and, instead of the wing's losing lift, the air comes through between the slat and the wing itself and maintains the airflow so that the wing continues to lift when the airplane is at a very low speed. An advantage of this is that, in getting out of a very small field, the machine can climb at a much steeper angle; it climbs no faster and takes just as long to rise to say 100 ft., but it allows the machine to climb more nearly vertically at the same speed without covering as much ground at that speed. Hence, where an ordinary type of airplane would hit the tops of trees before it reached the necessary height, this particular type will rise over them. The same principles apply when descending. Where an ordinary machine needs a much more acute angle to glide and so has to approach the ground at a greater distance from where it is to land, this type of wing is supposed to allow the machine to come in, say, over the tops of trees and to drop to the ground comparatively near the trees; so, a very much smaller landing space can be used. All experiments show that this sort of wing works perfectly well; but the difficulty lies in the operating mechanism of the movable parts. Apparently, experiments are being made to develop a satisfactory operating mechanism which is not heavy enough to eliminate any appreciable part of the benefit of the slots.

A small machine embodying that wing was considered for the United States Navy, for experimental purposes, but the contract was cancelled. So far, the wing seems

[5] M.S.A.E.—Consulting aeronautical engineer, Dayton, Ohio.
[6] M.S.A.E.—Chief of electrical division, General Motors Research Corporation, Dayton, Ohio.

to have been giving fairly good results. The trouble has been that the whole machine must be built for the purpose and, if the first experiment is not satisfactory, considerable time must elapse before preparation can be made for the next experiment. That is why the development has been so slow. But the other mechanism, the flap wing that I mentioned, is being used in the British Navy almost entirely on its float seaplanes and on land airplanes, because it definitely provides a much better landing-ability. One of this type, the Fairey "Flycatcher," has a speed of 145 m.p.h. when carrying all the things the Navy insists on putting on it, such as bomb racks and dock landing-hooks. Its slow-flying landing-speed is about 40 m.p.h. I have seen it put down on the ground at 25 m.p.h., and that is slow enough for anybody.

MR. UPSON:—Referring to the relative merit of airships and large airplanes, not very long ago I made a rather detailed comparison between the performance of the Barling bombing airplane and an hypothetical airship, lighter-than-air, of equal gross carriage capacity but having the proper horsepower to give it the same general characteristics of performance based on existing types of design; that is, without any reliance on improvement which we expect to make in the near future. On these assumptions we can build an airship of the same gross carrying capacity as the Barling airplane, one of a very moderate size for an airship, only a few hundred thousand cubic feet, which will travel at an equal speed with approximately equal power and carry more than double the useful load. At speeds appreciably below that, the airship is much superior, and the same would apply for sizes in excess of that here considered.

CHAIRMAN CRANE:—I strongly indorse what Mr. Hunt has said regarding the Shenandoah. Probably all of us helped pay for it, and I am entirely satisfied to have paid my share. Whatever we may think about the usefulness of the very large lighter-than-air craft, and the matter of handling it on the ground, it was only right engineering to allow our own Navy Department or our War Department actually to test by personal experience what the design, manufacture and subsequent control and operation of such a ship really means. The Germans provided a great amount of experience for us during the war, but it was at a distance of 3000 miles and those of us who have engaged in engineering development-work know that a mass of detailed experimental data exists that never gets through. The only way it is ever obtained is by actual personal contact with the work, and that applies particularly to the difficulties of doing a job. The good points of any of these jobs are very plain on the surface; they need little advertising. It is the other points, largely hidden, like the qualities of human nature, that we must find out about. Only one engineering departments exists, a national one, that has a chance actually to go through with the whole course of operation itself, from the initial study of the design down through the construction and subsequent operation; thus, it really knows the possibilities.

In the last war, we suffered here from a serious lack of preliminary information regarding what is possible. It was a tremendously difficult task, the choosing of the right kind of things to work on; that is, what kind of engines to build and what plans to follow. The choice that was finally made was surprisingly good, I think, in view of our very small fund of information when we began.

During the present period of peace and the reaction in Congress against expenditures for military purposes, the best we can hope for from our Army and our Navy is that they will be collecting information as to what is possible with various types of machine, with both lighter-than-air and heavier-than-air craft. That applies to the very large heavier-than-air machines just as it does to the very large lighter-than-air machines. Apparently, with all machines that use the air as a transportation medium, the real trouble lies in getting them off the ground and getting them back on the ground. That has always appeared to me to be the great difficulty with the lighter-than-air proposition, the tremendous ground crew required to operate it. If an aircraft line were operated from New York City to Chicago, probably the ground crew actually would be performing service for ½ hr. only in an entire day. The same argument occurs to me in relation to the discussion regarding the seaplane work for the Navy. The real tough problem is how to land; the float construction, how it can be made light and strong and watertight and stay that way.

There was less discussion about the wing construction, and we even hear less about engines than formerly. The same thing holds true of the landing gear on airplanes, and the type of design that will permit of a landing in a very small space.

One of the things that occurred during the war many times was the attempt to get around a table and have the people at the table make a sound engineering decision; it never worked and it never will work. The present work that is being done toward assembling a large volume of facts, of what happens when you do this and do that, and facts regarding construction and design, is the very greatest thing our Army and Navy could be doing to justify their existence just now.

EARNINGS OF INDUSTRIAL WORKERS

AVERAGE hourly earnings of American industrial wage-earners made a net gain of over 100 per cent in the last 10 years, according to a statement issued by the National Industrial Conference Board, New York City. Commenting upon this fact in a comprehensive survey of the trends of wages, hours and employment in manufacturing industries of the United States, the Board says that the extent to which this advance has been converted into increased earnings for the average wage-earner has been affected by the security of his employment and the ability of his employer to maintain a full working schedule. Periods of want and periods of plenty have succeeded each other with marked regularity in the last 10 years, but with employment no more uncertain today than it was 10 years ago, with wage rates more than 100 per cent higher, and average living costs increased only about 60 per cent, even after making due allowance for the improved standards of living, the wage-earner today appears to be in a much more advantageous position at the close of the decade than he was at its beginning.—*Economic World.*

Final Report on the 1924 California Air-Cleaner Tests

By A. H. HOFFMAN[1]

ANNUAL MEETING PAPER *Illustrated with* PHOTOGRAPHS AND DRAWINGS

ABSTRACT

RAPID wearing out of the engines of farm tractors, trucks and automobiles led the University of California to undertake a study of the dust problem and the efficiency of air-cleaners in removing field and road dust from the air before it passes into the engine. Work was begun in 1922 and several reports have been made on the methods devised and the progress made during the last 2 years. Results to June, 1924, were given in the paper published in THE JOURNAL of August, 1924. The present paper gives results of the studies to the end of 1924 and includes data from tests of 12 new makes or models of air-cleaner not previously tested or not fully tested.

Of outstanding importance is the discovery that the quantity of dust inspired by any cleaner or carbureter is greatly reduced if the intake is placed high and faces away from the direction of motion of the vehicle. The cleaners on two 3½-ton Liberty trucks used in road construction work in California, with intakes located 46 and 48 in. above ground and facing forward, encountered approximately 0.07 and 0.08 gram of dust per mile respectively, whereas two other trucks of the same make and model and used in the same work, which had no air-cleaners but whose intakes were directed backward, evidently encountered much less dust as the average engine wear in these two trucks was almost exactly the same as in the truck fitted with a cleaner that caught and held slightly more than 0.08 gram per mile but which probably passed as much dust into the engine as it caught and held. A 1-ton truck which had its intake located 47 in. from the ground and facing sidewise under the hood encountered slightly more than 0.001 gram of dust. This truck, however, was used mainly on paved roads.

The makes and models of cleaner tested since the last progress report was given at the Spring Lake Meeting of the Society last June are illustrated and described and the author presents graphs showing the efficiency of all the devices tested and the amount of restriction they imposed on the flow of air to the carbureter when clean and when they had been fed from 25 to 100 grams of No. 1 standard dust, which is entirely free from moisture, has a specific gravity of 0.680, and 98.60 per cent of which passes through a screen of 200 meshes per in.

The accompanying tables give the type, weight, material and dimensions of the 12 additional cleaners tested since June, 1924, the results obtained in service tests to determine the quantity of dust entering the carbureter intake, a summary of results of tests of the 12 cleaners showing their efficiency in service runs and the amount of restriction caused by each cleaner as measured in inches of water due to vacuum in a U-tube manometer, and results of a fill-up test of these cleaners to give a general indication of how a cleaner might act if subjected to gross neglect and abuse by determining how much or how little increase of restriction occurs when from 1 to 10 lb. of No. 2 standard dust has been fed to it.

Other tests of great importance which might be made would have as their objects the determination of length of time the cleaner will last in normal service, how long it will function without attention, amount of work or time required to keep it clean and in proper working condition, weak places in its construction and variation in efficiency among cleaners of the same make and model.

The University of California is preparing a program of laboratory tests of bearing wear, which is closely allied with the dust problem. The author says that the function of the University is not to do routine testing but to devise methods and prove them by their practical application. It is ready to undertake the task in cases where the regular test methods are not applicable, as in testing radiator-fan-type cleaners.

BECAUSE the engines of farm tractors, trucks and automobiles wore out too fast, the University of California Agricultural Experiment Station undertook to make tests of air-cleaners about 3 years ago. Service to agriculture was best accomplished indirectly in this case; that is, by serving manufacture. Both the manufacturer and the consumer will be benefited, beyond a doubt, if the "bugs" in a device are discovered and removed before the machine carrying the device reaches the user.

The University of California is not charged specifically by the State to do routine testing of air-cleaners. Our task is rather to devise methods for making needed tests, to prove the methods by sufficient practical applications and then to take up the next assignment. If the Agricultural Engineering Division of the University continues to test air-cleaners by its usual methods, additional assistants must be employed to do the work and it may become necessary to charge a fee to cover the expense. This does not apply in cases in which the regular test methods are inapplicable, for when a new method must be worked out we are ready to undertake the task, as for example in testing the radiator-fan type of air-cleaner.

A program of laboratory tests of bearing wear is being prepared. This proposed work is closely allied with the dust problem. How extensive this work will be it is impossible to state at present.

WHAT THE TESTS HAVE COVERED

In initiating the work of testing air-cleaners for internal-combustion engines in 1922, a method[2] was devised for testing the efficiency and vacuum of the cleaners and 30 cleaners, representing practically all the kinds then in the market, were tested and the results reported.[3] Preparations for a second series of tests, to include new makes and models and any not tested in the

[1] Agricultural engineering division, University of California, Davis, Cal.

[2] See *Agricultural Engineering*, June, 1923, p. 89 and July, 1923, p. 109.

[3] See University of California Agricultural Experiment Station Bulletin No. 362.

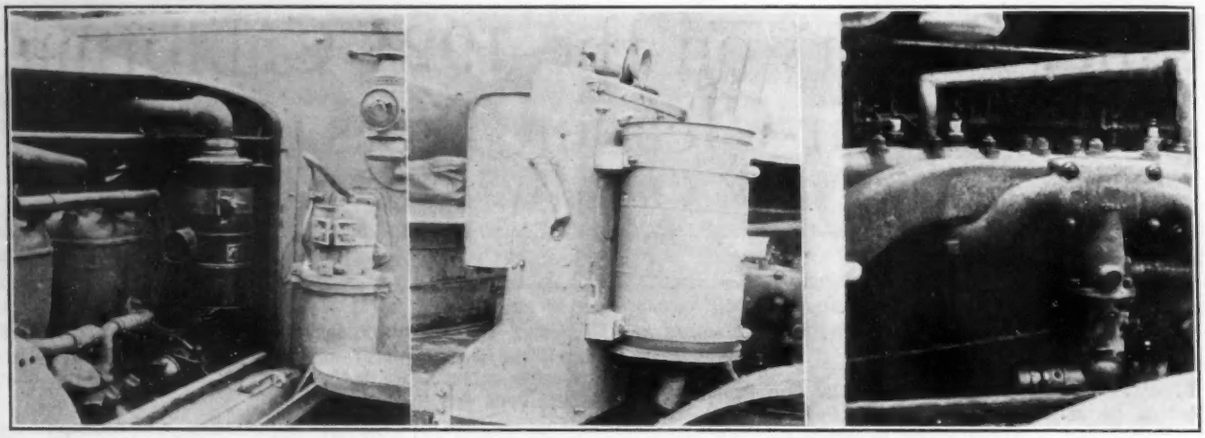

FIG. 1—POSITION OF CLEANERS AND THEIR INLETS ON VEHICLES IN ROAD-TESTS

On Liberty 3½-Ton Truck, at Left, the Inlet of Pomona Cleaner Was Under Rear of Hood, 46 In. above Ground and Facing Forward. Truck was Run 2800 Miles in 6 Months in California Road Construction Work. Dust Encountered per Mile Was 0.06996 Grams. On Another Truck of Same Make and Model Used in the Same Work, the Air Inlet Was Outside the Hood, as Shown at the Center, 48 In. above Ground and Facing Forward. Dust per Mile Held by the Cleaner Was 0.08095 Grams But Probably As Much More Passed Through into the Engine. On Two Other Similar Trucks Used in the Same Road Construction Work, the Unprotected Carbureter Inlets Were Under the Hood, as Shown at the Right, 38.5 In. above Ground and Directed toward the Rear. These Two Trucks Encountered Much Less Dust per Mile Than the One at the Left with Its Inlet Outside the Hood

first series, were made early in 1924. A progress report[4] was made at the Semi-Annual Meeting of the Society in June, 1924. The purpose in the present paper is to complete to date the report then made.

Four items were included in the 1924 California air-cleaner program. They were:

(1) Applying the laboratory test-method devised in 1922 to the new makes and models available
(2) Devising a method applicable to cleaners which could not be tested by the original method
(3) Determining how much dust an automobile or truck encounters in service
(4) Finding out how the use of air-cleaners affects the rate of engine wear

The second of these items is not yet ready for report. The fourth, which occasioned a 6-months' service test on eight trucks, was reported in another paper[5] presented at the 1925 Annual Meeting of the Society. The other two items furnish the subject matter of this paper.

[4] See THE JOURNAL, August, 1924, p. 140.
[5] See THE JOURNAL, February, 1925, p. 249.

AIR-INTAKE SHOULD BE HIGH AND DIRECTED TOWARD THE REAR

Table 1 gives the results of the service tests made to determine the quantity of dust per mile entering the carbureter intake. It was not realized when this work was planned that the location of the air-intake and the direction it faces have a marked effect on the amount of dust entering. The two Liberty trucks listed in the table were used in almost identical service but for different total periods of time and mileage traveled. In the first truck the intake of the cleaner was under the hood, 46 in. above the ground, and with the opening facing forward as shown at the left in Fig. 1. It encountered 0.06996 gram per mile. In the second truck the intake was 48 in. above the ground and facing forward but *outside of the hood*, as shown in the central view. The dust caught and held by the latter air-cleaner was 0.08095 gram per mile, or 16 per cent more than the total per mile encountered by the first. How much more dust passed the cleaner of the second truck and went into the engine is unknown, but that it was large,

TABLE 1—DUST PER MILE ENTERING CARBURETER OF TRUCK OR AUTOMOBILE

Car or Truck	Miles	Time Used From	Time Used To	Where Used	Dust Encountered, Grams	Dust per Mile, Grams	Intake Location	Intake Height, In.
1923 Dodge Touring	3,646	12/29/23	12/16/24	Northern California	10.15[a]	0.00277	Under hood, facing forward	35
1923 Ford Truck	2,153	6/ 5/24	10/ 9/24	Around Davis, Cal.	12.86[a]	0.00598	Under hood, facing forward	42
1920 Ford Touring	754	5/10/24	8/ 1/24	Near Grinnell, Iowa	0.73[a]	0.00097	Under hood, facing sidewise	39
3½-Ton Liberty Truck	2,800	4/ 1/24	10/ 1/24	Road construction in Northwestern California	195.90[a]	0.06996	Under hood, facing forward	46
3½-Ton Liberty Truck	1,983	4/ 1/24	10/ 1/24	Road construction in Northwestern California	160.52[b]	0.08095[b]	Outside of hood, facing forward	48
1-Ton International Harvester Speed Truck	6,375[c]	3/12/24	11/13/24	University Extension Farm	6.80[a]	0.00106	Under hood, facing sidewise	47

[a] Corrected to the basis of 100-per cent efficiency of the air-cleaner.
[b] Actual dust caught; no correction made for air-cleaner efficiency.
[c] 87 per cent of this distance was on paving.

TABLE 2—IDENTIFICATION FOR CLEANERS TESTED SINCE JUNE, 1924

No.	Make or Name	Type	Weight, Lb. Clean, Dry	Weight, Lb. Ready for Use	Outlets, Inside Diameter, In.	Outlets, Number	Inlets, Diameter or Size, In.	Body Proper, Height, Length and Width, In.	Materials Body	Materials Filter, if Any
32	Taco Siphon 1-A	Wet	45.6	56.2	1.75	2	0.50 x 1.50	12.0 x 15.0 x 6.0	Cast Iron	.....
36	Bennett	Combination	3.4	4.0[d]	1.90	1	2.00	3.5 x 6.5[e]	Sheet Steel	Fiber
38	Bennett	Combination	1.9	2.1[d]	1.40	1	1.50	2.6 x 4.5[e]	Sheet Steel	Fiber
46	Winslow 6 in.	Oil	7.3	10.2	1.81	1	2.00	8.5 x 6.0[e]	Sheet Steel	Fiber
49	Thompson	Dry	6.1	6.1	1.60	1	1.55	7.5[e] x 2.5	Cast Aluminum	.....
55	White	Oil	3.6	5.0[d]	1.56	8	0.63	5.0 x 9.0 x 5.0	Sheet Steel	Fiber
57	Simplex	Oil	10.1	11.3[d]	1.87	1	3.00	7.0[e] x 8.6	Sheet Steel and Cast Iron	Fiber
58	Pomona 161	Oil	8.1	10.0	1.66	1	2.50	12.0 x 5.5[e]	Sheet Steel	Wire
59	Midwest T-1	Oil	7.4	8.1	2.00	38	0.50	8.0 x 5.5	Cast Aluminum	Expanded Metal
60	Twister	Dry	0.5	0.5	2.00	1	3.00	3.1 x 4.0 x 3.1	Sheet Steel	.....
61	Case, Model OK	Oil	37.0	40.0	1.63	1	2.00	13.0 x 9.0 x 5.5	Cast Iron	Fiber
62	A.C.	Dry	2.5	2.5	1.42	1	1.64 x 1.70	5.8 x 5.8 x 3.7	Steel and Aluminum	.....

[d] Estimated; varies with kind of oil and time draining.
[e] Diameter.

possibly even larger than the total encountered by the first truck, is indicated by the fact that the engine wear per 1000 miles in the second truck was almost exactly the same as it was in the average of two other trucks in the same service which had no air-cleaners but had their air-intakes under the hood, 38.5 in. above ground and facing backward, as illustrated at the right in Fig. 1.

The tests are being continued. The first car of Table 1 is to be run another year, fitted with the same air-cleaner as before except that the air-intake of the cleaner now faces toward the rear instead of forward as shown in Fig. 2. One or more other cars of the same make are being equipped to determine the quantity of dust caught when the intakes are placed elsewhere under the hood. It seems evident that the best location under the hood would be as high as possible, about midway between the sides, well toward the rear and with the opening directed backward.

Twelve air-cleaners identified in Table 2 were given tests since the progress report[e] previously referred to was made. Some of these were included in the report but for one reason or another required additional tests. These tests are here reported, with the averages including all tests to date. Table 3 gives a summary of

[e] See University of California Agricultural Experiment Station Bulletin No. 362.

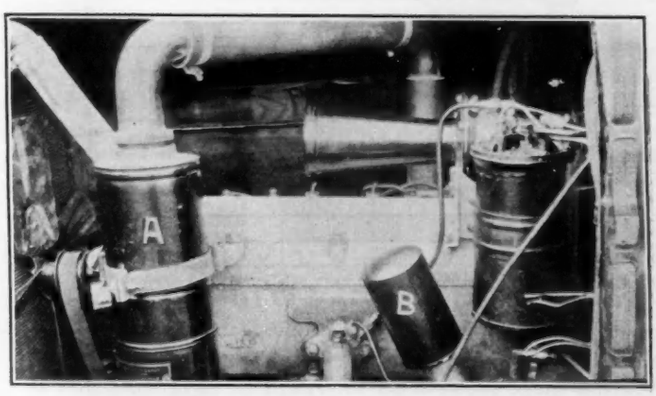

FIG. 2—DODGE TOURING CAR WITH CLEANER UNDER HOOD AND INLET FACING FORWARD

The Inlet of Pomona Cleaner Is 35 In. Above Ground. *B* is an Oil-Filter-Type Breather Cleaner. The Car Was Run 3646 Miles in 1 Year and the Dust per Mile Was 0.00277 Grams

TABLE 3—SUMMARY OF RESULTS OF TESTS RUN SINCE JUNE, 1924

No.	Make or Trade Name	Dust Separating Efficiency, Per Cent: Average of All Tests	Service Run	Low Water or Oil	Abrasive Removed by Cleaner in Service Run, Per Cent[f]	Vacuum, In. of Water at 20.4 Hp. and 1200 R.P.M.: Cleaner Clean	After 100 Grams of No. 1 Standard Dust Was Fed In	Vacuum, In. of Water at 9 Hp. and 800 R.P.M.: Cleaner Clean	After 100 Grams of No. 1 Standard Dust Was Fed In
32	Taco Siphon 1-A	86.9	96.8	76.9	96.8	5 3/8	5 3/8		
36	Bennett	95.7	99.2	...	98.7	2 9/16	53 3/8		
									(50 gr.)
38	Bennett	82.6	71.9	...	80.2			3 1/16	19 1/8
46	Winslow 6 In.	93.0	98.3	...	99.8	5½	5½	1 11/16	1 11/16
49	Thompson	35.7	9.6	...	7.7	5¾	5¾	2	2
55	White	99.2	98.5	...	99.6	5 1/16	6¾	2¼	3 1/8
57	Simplex	98.9	98.5	...	98.5	1	1 5/8		
58	Pomona 161	98.0	95.4	98.6	95.6	2¾	2¾		
59	Midwest T-1	91.7	89.7	...	90.5	¾	¾		
60	Twister	40.7	39.2	...	Lost	1 3/16	1 3/16		
61	Case Model OK	98.6	98.8	...	98.6	2¾	3 1/16		
62	A.C.[g]	67.7	Lost	...	75.7[f]	4 5/8	4 5/8	1 3/16	1 3/16

[f] Chemical determinations by Dr. Charles S. Bisson and Prof. J. G. Sewell.
[g] A defect was found in this cleaner after this report was prepared and incorporated in the graphs, hence results with it are of doubtful accuracy.
[f] On light load run.

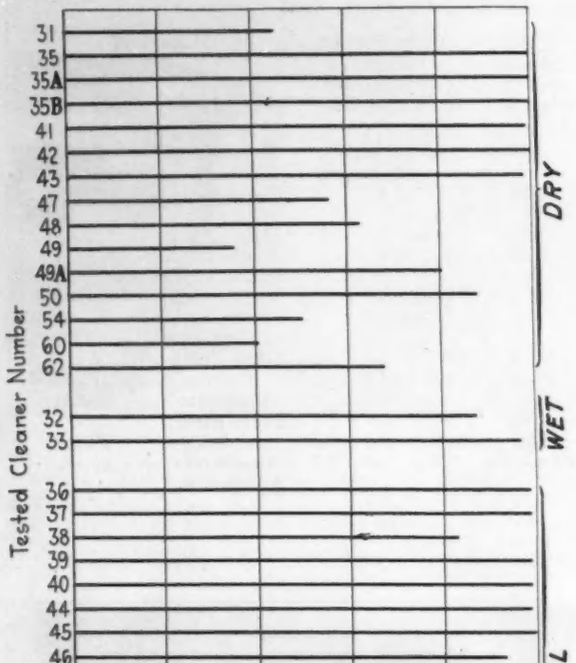

FIG. 3—DUST-SEPARATING EFFICIENCY OF AIR-CLEANER

This Chart Shows What Percentage of No. 1 Standard Dust Fed to Each Cleaner Was Stopped and Held by It in the 1924 Tests. For Identification of the Several Cleaners, See Table 2 Herewith, and Table 7 THE JOURNAL, August, 1924, p. 147

the regular tests on the 12 cleaners. Table 4 gives the results of all the fill-up tests, which are explained hereinafter, of the 1924 series. The graphs of efficiency and vacuum that are reproduced in Figs. 3 and 4 respectively include all the cleaners regularly tested in that series. Those not identified in Table 2 are in the identification table of the progress report.

NEW CLEANERS TESTED SINCE LAST JUNE

Cleaner No. 59, Midwest T-1, at the extreme left of Fig. 5, is of the oil-filter type. The filter element consists of a set of expanded-metal discs mounted on a horizontal shaft. The lower segments of the discs dip into oil. This placing enables periodic turning of the filter by hand to wash off accumulated dust and to re-oil the discs. The oil reservoir is formed by the lower part of the housing. The openings in the filter discs are placed alternately so that the air must change direction repeatedly in passing through them.

Cleaner No. 60, Twister, shown at the center, is of the dry centrifugal type. It consists of a cylinder placed horizontally, a set of four stationary vanes placed spirally in the intake, an outlet tube about half the length of the cylinder and a small dust receptacle. The vanes serve to impart spiral motion to the entering air. The separated dust falls through a circular opening into the receptacle provided for it. The cleansed air enters the outlet tube at approximately the center of the cylindrical shell.

TABLE 4—SUMMARY OF 1924 SERIES FILL-UP TESTS

Cleaner No.	Dust in from Previous Runs, Grams	No. 2 Standard Dust Fed, Lb.	Dust Passing Cleaner, Oz.	Vacuum at 20.4 Hp. and 1200 R.P.M., In. of Water, Cleaner Clean	At End of Test
32	100	3	0.25	5 3/8[i]	10 9/16
35	100	1 11/16	[g]	¾	17 5/8
42	100	3	8.80[h]	3 1/8	21 1/8
44	100	10	[g]	2 1/16	4 3/4
52	100	3	[g]	4 7/8	23 1/4
53	100	3	0.50	3/4	2
55	100	1	[g]	5 1/16	22 3/4
57	100	1	[g]	1 5/16	38 3/4
58	150	3	[g]	2	3 1/16
61	100	2	11.25	2 3/4	14 7/8

[g] Not weighable on ¼-oz. sensitive scale.
[h] Slipped between edge of rubber disc and metal frame.
[i] Average; at high-water level 6 in., at low 4¾ in.

The third cleaner, No. 61, the Case Model OK, which is not shown, was of oil-filter type. It is designed especially for the Wallis tractor but has some features of

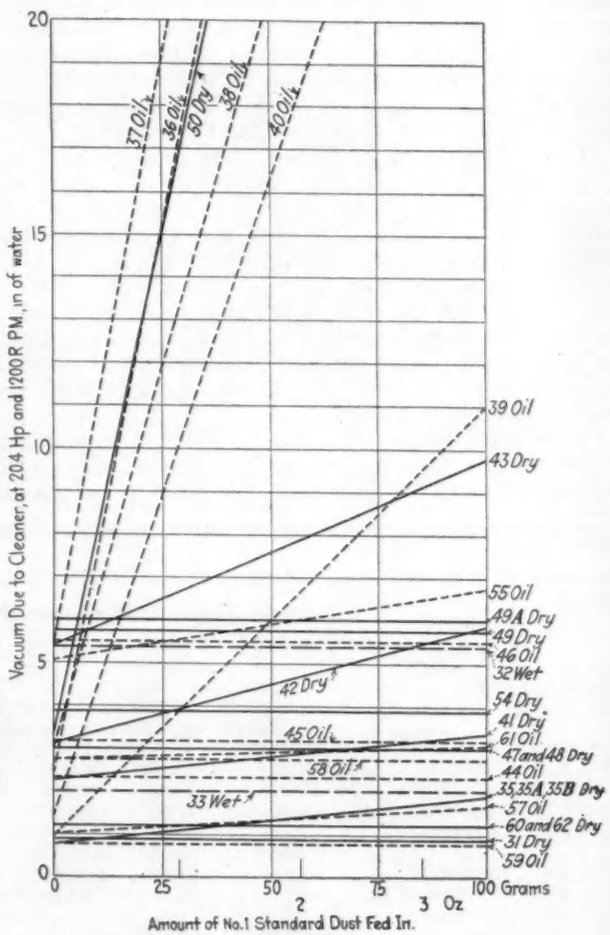

FIG. 4—VACUUM GRAPH SHOWING RESTRICTION CAUSED BY AIR-CLEANERS

The Lines at the Left End Show the Amount of Restriction, in Inches of Water, with the Air-Cleaners Clean and at the Right the Amount of Restriction when 100 Grams of No. 1 Standard Dust Had Been Fed into the Cleaner Intake. All the Cleaners Tested in the 1924 Series Showed Some Restriction when Used with a Wiedely M A U Four-Cylinder Engine when Developing 20.4 Hp. at 1200 R.P.M. No. 1 Standard Dust Passes 98.60 Per Cent through a Screen of 200 Meshes per In., Has a Specific Gravity of 0.68 when Well Shaken Down, and Contains No Moisture

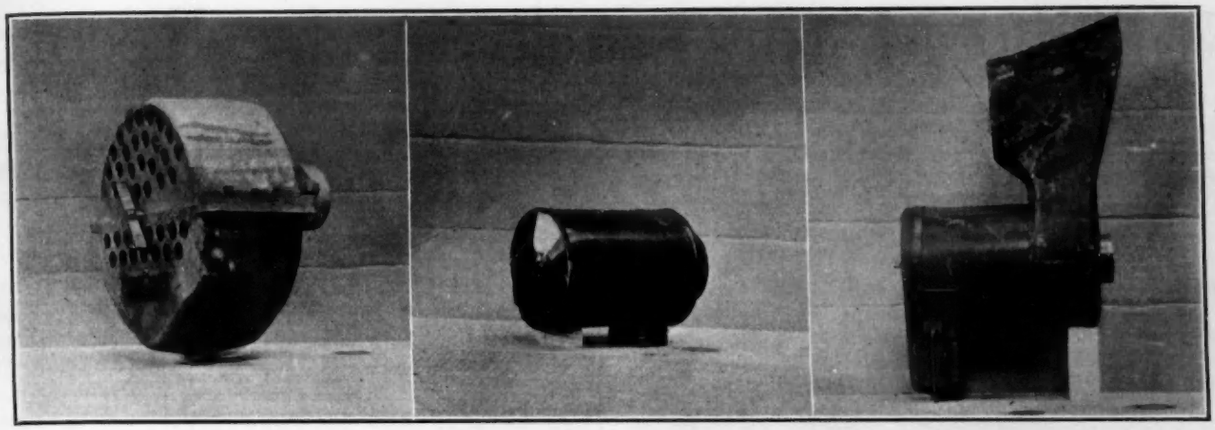

FIG. 5—THREE OF THE NEW AIR-CLEANERS TESTED SINCE JUNE, 1924, AND NOT PREVIOUSLY REPORTED ON

No. 59, Midwest T-1, at the Left, Contains Perforated Expanded-Metal Discs with the Perforations in the Several Discs Staggered So That the Air Changes Its Course in Passing Through. The Lower Segment of Each Disc Is Immersed in Oil in the Lower Part of the Housing and Turning the Shaft by the Handle at the Left Re-Oils the Filter. No. 60, Twister, in the Center, Has Four Stationary Vanes at the Left End That Impart a Whirling Motion to the Entering Air and Separate the Dust by Centrifugal Action and Gravity. The Dust Escapes to a Receptacle Below. No. 62, A. C., at the Right, Has a Stove Cast Integral with a Tangential Inlet at Upper Right Which Gives the Air a Whirling Motion That Is Augmented by Stationary Vanes between the Antechamber and Cylinder Proper. Dust Escapes to a Receptacle Below at the Left. The Air Reverses Direction and Passes Out Through an Axially Disposed Tube, Being Straightened Out by a Modified Spiral Vane

general interest. The primary air-inlet and the seasonal cold-air inlet are both screened and placed well up and at opposite ends of the exhaust-manifold, thus incidentally utilizing the periscope principle to reduce the amount of dust to be handled. The cleaner proper is a casting having several compartments. An inspection plate at the top gives access to the fiber filter, which may be removed for washing. A second plate on the side gives access to the several compartments to permit inspection and to facilitate removal of accumulated dust and renewal of the oil in the receptacle in the base. The dusty air enters at the top and passes down a tube cast in one end of the cleaner. At the bottom of the tube and at a level near that of the oil in the reservoir, the air stream changes direction 180 deg. and passes up a second cast tube. It carries finely divided oil with it to the space above the filter. The air then passes downward through the filter and out to the carbureter.

Cleaner No. 62, A. C., illustrated at the right of Fig. 5, is of the dry centrifugal type. It has a cylindrical antechamber with a tangentially placed inlet, a horizontally placed cylindrical shell, a set of 10 stationary vanes placed spirally in the inlet proper, an outlet tube containing a modified spiral guide vane and a dust receptacle. A stove is cast on the primary inlet tube. The tangential inlet imparts a whirling motion to the air in the antechamber. This motion is augmented by the vanes in the inlet to the cylinder proper. The separated dust particles follow spiral paths to an opening in the cylindrical shell and fall or shoot into the dust receptacle below. The cleansed air enters the outlet tube at about the midpoint of the cylinder proper. The whirling motion of the outgoing air-stream is destroyed by the modified spiral vane. The outlet tube passes outward through the antechamber, being coaxial with it.

The other cleaners for which results are given in this paper were described in the progress report.[9]

CLASSED AS DRY, WET AND OIL TYPES FOR CONVENIENCE

Our classification of air-cleaners into dry, wet and oil types has been found convenient in use. It is open to objection, however, as being not adequately descriptive in some cases. The three terms were adopted in reporting the work of the original test series in 1922 and were received with apparent general satisfaction. "Wet" was understood to mean a type ordinarily using water in its operation; "oil," ordinarily using oil in any manner; and "dry," requiring no liquid for its action.

It is realized that various combinations of these principles are possible and that the proposed classification is often not completely descriptive. Thus, cleaners Nos. 36, 37, 38, 44, 45, 46, 53 and 58 all combine centrifugal action with oil-filtering action, but they have all been classed for convenience with other cleaners using oil in any way. About half the 60 odd cleaners so far tested use the inertia principle in some way. Nevertheless it was deemed inadvisable to adopt a classification on this as a basis, since sub-classification would then have been imperative.

HOW THE LABORATORY TESTS WERE MADE

The cleaners tested were furnished by the manufacturers, or with their consent. Those were chosen, in general, that were of a size suitable for a specified four-cylinder engine operating at 1200 r.p.m. and 20.4 hp. While the specified engine draws its air through the cleaner under test, a 50-gram portion of a dry composite standard dust[10] is fed at a uniform rate and finely divided into the air entering the cleaner. Between the cleaner under test and the carbureter is placed an "absolute cleaner"[11] which catches most of the dust lost by the cleaner under test and enables determination of the remainder. The cleaner under test is credited with catching the dust not accounted for by the absolute cleaner. Its efficiency is obtained by subtracting from 100 twice the number of grams of dust caught in the absolute cleaner.

For determining the vacuum or restriction, a U-tube manometer is connected between the outlet and inlet of the cleaner under test. Each cleaner is studied to make sure that the piezometer connection used does not cause appreciable error, the object being to measure the pressure-drop properly chargeable to the cleaner alone without its connections.

[9] See University of California Agricultural Experiment Station Bulletin No. 362.

[10] See *Agricultural Engineering*, June, 1923, p. 89 and July, 1923, p. 109.

[11] See THE JOURNAL, August, 1924, p. 141.

(*Concluded on p.* 378)

Utilizing Motor-Truck Service-Records

By S. V. NORTON[1]

SERVICE MEETING PAPER *Illustrated with* CHARTS AND PHOTOGRAPHS

ABSTRACT

PROFITABLE use of service records, at the factory and in the field, depends upon effectively organized effort to make them specifically available to the persons who are in a position to make direct application of the information. To this end, the company represented by the author maintains a "manufacturing committee" composed of the heads of the principal departments, its meetings being held at stated intervals under the direction of the general manager or his assistant, which acts upon the problems presented by the service department.

The service engineer attached to the technical division follows-up the complaints recorded and, in connection with the engineering department, develops practicable remedies. Bulletins are then issued to the field organization. They notify the service-stations of improvements in the parts or in methods of service. Through a continuous process of education of the field service-station personnel by the service road-men maximum use of the information resulting from the company's general experience is accomplished.

FEW executives in the automotive industry realize the extent to which the records of their service departments can be utilized to support all the other divisions of their organizations. So much has been said about the inability of the average service department to provide dependable service data that, during the last few years, progressive service-managers have been turning their attention to this phase of their duties. In the truck industry, at least, the day has passed for depending upon hit-or-miss records, or upon the memory of the oldest living representatives of the service department for supplying information or making recommendations to the chief engineer or to the general manager. To speak with authority, the service-manager must have evidence based upon definite records from many vehicles and service-stations in all parts of the Country. Moreover, these records must be compiled and presented in the most convincing and helpful manner possible, so that the management can make use of them easily.

The object of this paper is to describe, as briefly as possible, the methods developed by the General Motors Truck Co. for making profitable use of service records not only at the factory but in the field. The subject might lead into so many interesting by-paths that it seems advisable to confine the treatment to skeleton or outline form, sketching in the main points of our system and suggesting, rather than describing in detail, the many ways in which we make use of the information we obtain.

[1] A.S.A.E.—Service-Manager, General Motors Truck Co., Pontiac, Mich.

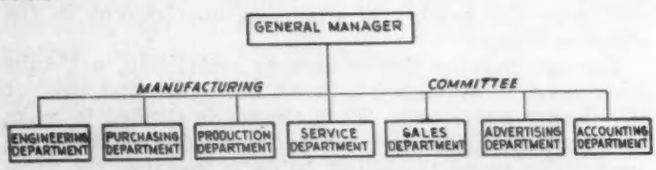

FIG. 1—CHART SHOWING THE ORGANIZATION OF THE MANUFACTURING COMMITTEE

This Committee, Which Meets at Stated Intervals under the Direction of the General Manager or His Assistant, Is Made Up of the Heads of the Principal Departments

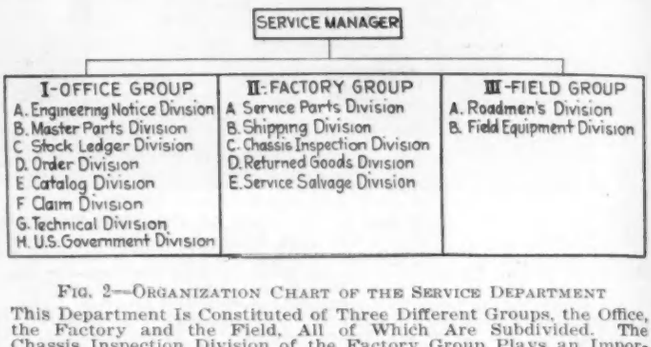

FIG. 2—ORGANIZATION CHART OF THE SERVICE DEPARTMENT

This Department Is Constituted of Three Different Groups, the Office, the Factory and the Field, All of Which Are Subdivided. The Chassis Inspection Division of the Factory Group Plays an Important Part in the General Scheme

To help visualize the subject, illustrations presenting organization charts, reproductions of the forms used and views of operations at our factory and on the General Motors proving grounds are included.

THE MANUFACTURING COMMITTEE

Fig. 1 shows the organization of what is called the manufacturing committee of our company, composed of the heads of the principal departments. Its meetings are held at stated intervals under the direction of the general manager or his assistant. The chart shows the service department in its relation to the other departments.

SERVICE-DEPARTMENT ORGANIZATION

Fig. 2 shows the organization of the service department. It has three groups; office, factory and field. It is hardly necessary to describe the functions of all the divisions within these groups as the names imply sufficiently the scope of their work. It is important to note division C of the factory group, however, as this plays an important part in our scheme. Since the service department is responsible for keeping our trucks running after they are sold, our final inspection is handled by our service department rather than by the production department as is the case in the majority of car and truck factories. This arrangement tends to maintain the quality of our output, as the service department is naturally more interested in quality than quantity.

Fig. 3 shows the organization of our service inspection at the factory. The final inspection is handled by the service department. Thus, when our production is running normally, the inspection of chassis is by the following groups of inspectors, under the direction of the final inspector, who reports directly to the service-manager:

(1) Chassis line
(2) Test room
(3) Special equipment
(4) Final assembly
(5) Loading dock

Upon complaint by any of these inspectors to the final inspector, any chassis can be held up by the latter until he is satisfied that the trouble has been corrected by the production department.

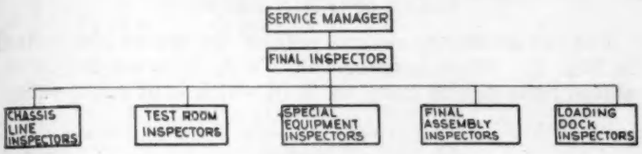

FIG. 3—ORGANIZATION CHART OF SERVICE INSPECTION
The Final Inspection Is Handled by the Service Department instead of the Production Department

After the chassis is completed on the assembly line and receives a serial number, it is run onto the test blocks, shown in Fig. 4, where an inspector places it under a load representing its rated carrying capacity as measured by a loadometer. The job is then tested under its own power against a dynamometer. This test, which lasts from 1½ to 2 hr. for each chassis, is equivalent to running the truck on the road for approximately 15 or 18 miles, and determines whether the chassis meets our requirements in respect to power, oil and gasoline consumption, noise and the like, and in what respects it requires further attention if it does not measure up to our standard. Fig. 5 shows the inspection at the loading dock.

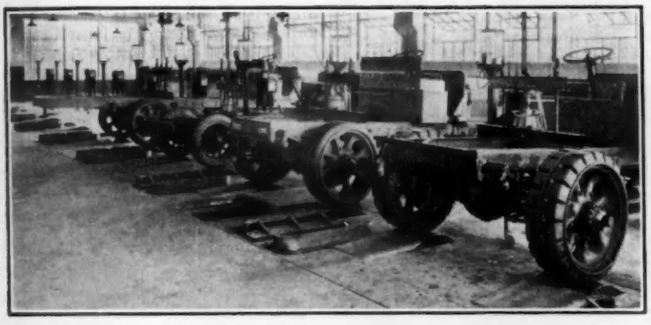

FIG. 4—DYNAMOMETER TEST OF COMPLETED TRUCKS
This Is Conducted by the Test-Room Inspectors Who Form One Group in the Service Inspection Organization. The Test Lasts from 1½ to 2 Hr. and Is the Equivalent of Running the Truck on the Road for Approximately 15 or 18 Miles

Fig. 6 is a reproduction of the report used in recording the performance of the dynamometer test. It is filed in the service department, where it constitutes the first sheet in the life history of the truck.

TESTING CHASSIS BEFORE SHIPMENT

From time to time we select at random chassis that have been approved and give them actual road-tests to check the block tests, and to see that they perform satisfactorily when driven. Fig. 7 shows the General Motors proving ground, where some of these tests are made. If either the block or the road-test shows that the job is in any way unsatisfactory, a red rejection tag is fastened to the steering-wheel, indicating the cause of the trouble. This tag is removed only after the final inspector is satisfied that the trouble has been corrected.

FIELD SERVICE-INSPECTIONS

To obtain a check on both our production department and our service-inspection division, we have provided our branch offices and distributors with service-inspection report-forms. As these reports are divided into some 60 divisions based upon records kept for many years by our engineering department, the information we obtain from them is easily coordinated with past records. Fig. 8 shows the form used for this purpose.

On these reports our branch offices and distributors check the condition of new chassis when they arrive at their destination, indicating troubles due to unsatisfactory material or workmanship, careless inspection at the factory and damage in loading or in transit. They are mailed to the factory, recorded by the technical division

FIG. 5—TRUCKS UNDERGOING A FINAL INSPECTION AT THE LOADING DOCK
This Is the Last Inspection before Shipment. At This Point, as at Any Other, an Inspector Can Hold Up Any Chassis until Satisfied That the Production Department Has Corrected All Trouble Discovered

in the service-complaint file, which is explained later, and sent to our final inspector before filing. A follow-up is kept to make certain that troubles so reported are investigated and corrected.

CHASSIS TEST REPORT

Chassis No. _____ Motor No. _____
Tire Equipment Front _____ Rear _____
Gear Ratio _____ Starter _____ Generator _____
Valve Clearance Before Test _____ Oil Temp. _____ Oil Pressure _____
Special Equipment-If Any _____
_____
Defects Corrected Before Test _____
_____
Tested On Block No. _____ Load Applied _____
Friction Load Less Motor At _____ M.P.H. _____ Start _____ Finish _____
Time Run _____
Friction Load With Motor At _____ M.P.H. _____ Start _____ Finish _____
Time Run _____
Gas Reading _____ Gal.
H.P. Generated In High Gear _____ Start _____ Finish _____
M.P.H. _____ Gas Consumption _____ Mileage _____
Valve Clearance _____ Adjust To .008 To .012
Compression #1 _____ #2 _____ #3 _____ #4 _____
Set Governor
H.P. Generated High Gear _____ Start _____ Finish _____
M.P.H. _____ Gas Consumption _____ Mileage _____
H.P. Generated 2nd Speed _____ Start _____ Finish _____
M.P.H. _____ Gas Consumption _____ Mileage _____
H.P. Generated 1st Speed _____ Start _____ Finish _____
M.P.H. _____ Gas Consumption _____ Mileage _____
Oil Temp. _____ Oil Pressure _____
Water Temp. Before Test _____ Maximum Temp. _____
Room Temp. _____
Remarks _____
Tested By _____ Approved _____

FIG. 6—FORM FOR RECORDING THE RESULTS OF THE DYNAMOMETER TEST
This Report Is Filed in the Service Department and Constitutes the First Sheet in the Life History of the Truck

FIG. 7—CONDUCTING ROAD-TESTS OF TRUCKS

From Time to Time Chassis That Have Passed the Dynamometer Test Are Selected at Random and Given a Road-Test To Check Up the Earlier Test and To See That Their Performance when Driven Is Satisfactory

REPORTS ON TRUCKS IN SERVICE

The next step is to secure reports on trucks that have been sold and have been put into actual operation. For this purpose we use the inspection-report form shown in Fig. 8, but the service-station indicates in the space provided the reason the truck has come in; whether for routine inspection, for overhauling, or for repairs necessitated by accident. They are handled at the factory in the same manner as are the reports on new trucks, and

Form 0542-B

This Space for Factory Use

Rec'd Recorded

Referred to

Reason for Inspection.
Routine
In for repairs
Accident
New ×

General Motors Truck Co., Inspection Report

OWNER General Motors Truck Company Br. or Dist. Indianapolis.

ADDRESS 434 N. Capitol Ave. Inspector C.S. Gerking. Date 2-7-24

BUSINESS City Indianapolis Driver Engine No. 80-10063

Body Roads Daily Mileage Truck New or in Use Yrs. New Mo's Chassis No. K1623389

√	Item	Division	√	Item	Division	√	Item	Division	√	Item	Division
	1	Front Axle		17	Radius Rods		30	Timing Gears		44	Propeller Shaft
	2	Front Wheels		18	Carburetor	×	31	Valves,Spgs.,Tap'ts		45	Frame
	3	Front Tires		19	Magneto		32	Oil Leaks in Engine		46	Seat & Dash
	4	Front Springs		20	Spark Plugs		33	Oil Pump & System		47	Hood
	5	Rear Axle	×	21	Generator		34	Oil—Quantity		48	Radiator & Conn.
	6	Rear Wheels		22	Starting Motor		34A	Oil—Condition	×	49	Fuel Tank & Line
	7	Rear Tires		23	Starting Switch		34B	Oil—Mi. per Gal.		50	Muffler
	8	Rear Springs		24	Instrument Panel		35	Oil—Pan		51	Lamps & Wiring
×	9	Steering Gear		25	Engine Power		36	Fan and Belt		52	Fenders & Steps
×	10	Spark & T.Controls		25A	Ignition	×	37	Water Pump		53	Mud Pans
	11	Brake Control		25B	Carburetion	×	38	Governor		54	Battery
	12	Brakes		25C	COMPRESSION 1 2 3 4		39	Cylinder Block		55	Tool Equipment
	13	Clutch Control		26	Carbon Deposit		40	Cylinder Sleeves		56	Spec. Equipment
	14	Clutch		27	Main Bearings		41	Pistons & Rings		57	Chassis Lubrication
	15	Transmission		28	Connecting Rods		42	Manifolds & Ht.Jkt.	×	58	Horn
	16	Gear Shift		29	Wrist Pins		43	Gaskets		59	Miscellaneous

Check above if O.K. If not, state details below, referring to item numbers. SEE REVERSE SIDE

FIG. 8—FIELD SERVICE-INSPECTION FORM

The Condition of Each New Chassis when It Arrives at Its Destination Is Checked by the Branch or the Distributor Receiving It. This Indicates Troubles Due to Unsatisfactory Material or Workmanship, Careless Inspection at the Factory or Damage in Loading or in Transit

the information obtained enables us to learn in what ways our trucks are giving trouble in service.

Fig. 9 is a composite report made up to include several different kinds of complaint to show various ways in which the information is used. The report is of definite value because it shows the

(1) Name of the customer
(2) Location
(3) Kind of business
(4) Average daily mileage and whether on paved or unpaved roads
(5) Chassis number
(6) Engine number
(7) Date of inspection
(8) Length of time the truck has been in use

VALUE OF FIELD REPORTS

Fig. 10 shows the reverse side of the report illustrated in Fig. 9. When properly filled out, this enables us to obtain information from the field which is of great value.

Form 0542-B

This Space for Factory Use

Rec'd Recorded

Referred to

Reason for Inspection.
Routine
In for repairs
Accident
New

General Motors Truck Co., Inspection Report

OWNER U. G. I. Co. Br. or Dist. Philadelphia Branch,

ADDRESS Philadelphia, Pa. Inspector W. J. Sittner Date 6-24-24

BUSINESS Gas Extentions City Driver Thompson Engine No. 80-7339

Body Screen Roads Paved Daily Mileage 50 Truck New or in Use Yrs. 1 Mo's 2 Chassis No. K1620670

√	Item	Division	√	Item	Division	√	Item	Division	√	Item	Division
	1	Front Axle	×	17	Radius Rods	×	30	Timing Gears		44	Propeller Shaft
	2	Front Wheels		18	Carburetor	×	31	Valves,Spgs.,Tap'ts		45	Frame
	3	Front Tires		19	Magneto		32	Oil Leaks in Engine		46	Seat & Dash
	4	Front Springs	×	20	Spark Plugs		33	Oil Pump&System		47	Hood
	5	Rear Axle		21	Generator		34	Oil—Quantity	×	48	Radiator & Conn.
	6	Rear Wheels		22	Starting Motor		34A	Oil—Condition		49	Fuel Tank & Line
	7	Rear Tires		23	Starting Switch		34B	Oil—Mi. per Gal.		50	Muffler
×	8	Rear Springs		24	Instrument Panel		35	Oil—Pan		51	Lamps & Wiring
	9	Steering Gear		25	Engine Power		36	Fan and Belt		52	Fenders & Steps
	10	Spark & T.Controls		25A	Ignition		37	Water Pump		53	Mud Pans
	11	Brake Control		25B	Carburetion		38	Governor		54	Battery
	12	Brakes		25C	COMPRESSION 1 2 3 4		39	Cylinder Block		55	Tool Equipment
	13	Clutch Control		26	Carbon Deposit		40	Cylinder Sleeves		56	Spec. Equipment
×	14	Clutch		27	Main Bearings		41	Pistons & Rings		57	Chassis Lubrication
	15	Transmission		28	Connecting Rods		42	Manifolds & Ht.Jkt.		58	Horn
	16	Gear Shift		29	Wrist Pins	×	43	Gaskets		59	Miscellaneous

Check above if O.K. If not, state details below, referring to item numbers. SEE REVERSE SIDE

FIG. 9—SERVICE-INSPECTION REPORT ON USED CHASSIS

These Reports Are Filled Out by the Service-Station when a Truck Is Brought In for Routine Inspection, Overhauling or Repairs in Case of Accident. Such a Report when Properly Filled Out Shows How the Vehicles Give Trouble in Service

IMPORTANT

Please fill in the information requested below on every GMC Model K truck that you inspect or work on:

CONDITIONS COMPLAINED OF:—State the complaint made by owner or operator, such as "Truck won't pull," "Engine hard to start," "Engine knocks," "Uses too much oil or gas," "Noisy rear end," "Transmission won't stay in gear" "Body sags to one side," "Truck steers hard," "Parts broken or damaged."

2. CONDITIONS FOUND:—State what you found and what you consider to be the actual cause or causes of such complaints

3. ACTION TAKEN:—Tell what you did to correct the trouble described in Section 2

4. RESULTS:—Tell briefly the results of operations described in Section 3

5. SUGGESTIONS OR REMARKS:—Jot down any suggestions or remarks you care to make for the benefit of the owner, service station manager, or the factory.

FIG. 10—REVERSE SIDE OF THE SERVICE-INSPECTION REPORT ON USED CHASSIS

This Has Spaces for Recording the Conditions Complained of by the Operator, the Conditions Found by the Service-Station To Be the Causes of the Complaints, the Steps Taken by the Service-Station to Correct the Troubles and the Results Obtained, as Well as Any Suggestions

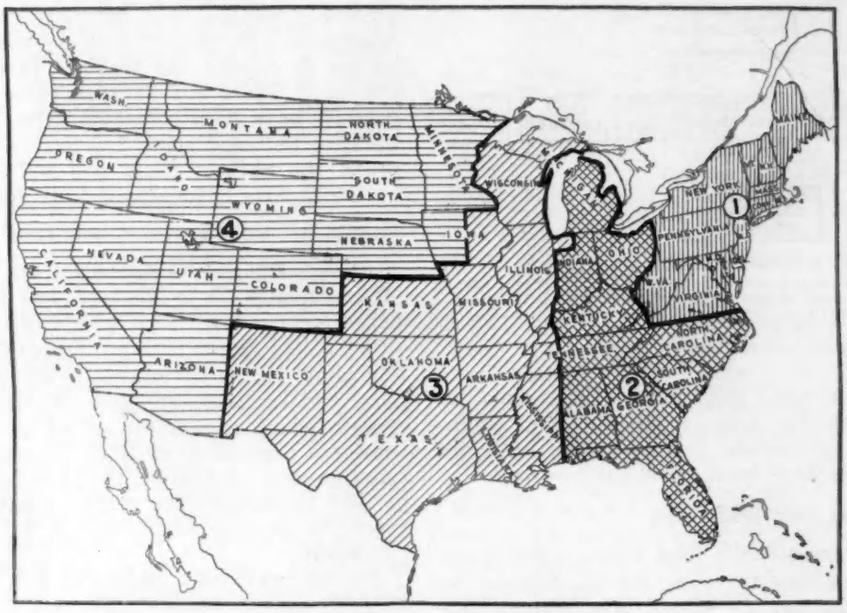

FIG. 11—FIELD SERVICE ZONES
Each of These Zones, Which Contains Approximately the Same Number of Trucks Although the Areas Vary Considerably, Has a Field Service-Man Who Calls upon the Branches, Distributors and Dealers Every 3 or 4 Months. These Men Send in Written Reports of the Calls Made as Well as Letters Describing in Detail Any Unusual Troubles Encountered

For example, we learn: (*a*) the conditions complained of by the operator, which can be regarded as the symptoms of the trouble; (*b*) the conditions found by the service-station to be the causes of the complaints; (*c*) the action taken by the service-station to correct the troubles, which gives us a line on whether the service-station is using the latest suggestions from the factory and enables us to know whether our bulletins have been received and read; (*d*) the results of such action; and (*e*) beneficial suggestions for the truck owner, the service-station manager or the factory.

At first, we found it difficult to get our service-stations to make these reports out and send them to us. It has taken much educational and missionary work to get them to appreciate their value. We have made excellent progress, however, largely by explaining how we use the information at the factory, and how it can be utilized in the field. The best method has been to "sell" the branch manager or the distributor himself, and he will then make the necessary arrangements with his staff to have the reports made out and sent to the factory.

ANALYSIS OF REPORTS

By means of these reports, which are being used more and more by our field organization, we have been able to analyze complaints according to: (*a*) territory, whether hilly or flat country and as to good or bad roads; (*b*) model or capacity of truck; and (*c*) kind of business. From time to time, if we wish to check-up on a certain trouble, these reports furnish dependable information as to its extent, and we need not be stampeded by alarmist letters or verbal reports from individual service-stations. At the same time we can take prompt action, if we see that the trouble is becoming widespread, before it reaches the proportions of an epidemic.

LETTERS FROM TRUCK USERS

Another valuable means of securing information is through letters we receive from truck operators. The sales department furnishes the names and addresses of new purchasers of our trucks and, as soon as possible after we have this information, we write the buyers expressing our appreciation of the fact that they have bought our product and asking them to let us know how the new truck is performing. We also invite them to write us if they have troubles in the future which are not adjusted satisfactorily by our local representatives. The replies to these letters, and any letters of complaint from truck operators, are handled by the service department and are followed-up through our nearest branch

COMPLAINT INDEX – MODEL "K" TRUCKS DIVISION No.5 – REAR AXLE

Date	Report	From	Chassis No.	Time in Serv.	Complaints in Detail
6-26	Letter	Buffalo	K16	13 M	
6-25	Letter	G.R.Kurtz	K41	New	
4-28	Letter	Sibra		6 M	
4-28	Letter	Sibra	K16	7 M	
4-28	Letter	Sibra	1268-7	12 M	
					Received in July
7-1	Letter	Louisville	K16s	12 M	
6-24	Letter	Sibra Los A'g'l's	K16 - K41	4 M	
4-4	Claim	Atlanta	K417356	8 M	
4-4	Claim	Atlanta	K417356	8 M	
4-4	Claim	Atlanta	K417356	8 M	
4-25	Claim	Charlotte	K413079	12 M	
7-7	Letter	Troxell	K16	7 M	
6-27	Letter	Hickman	K16	3 M	
7-19	Letter	Hickman	All		
7-22	Insp.	Cleveland	K1624566	New	
7-15	Insp.	Philadelphia	K1622300	8 M	
7-12	Insp.	New York	K1624540	4 M	
7-15	Insp.	Philadelphia	K4111015	9 wk	
7-12	Insp.	Hickman	K1622017	4 M	
6-26	Insp.	Pontiac	K418106	15 M	
6-24	Insp.	Boston	K418717	10 M	
7-11	Insp.	Dallas	K416827	11 M	
7-15	Insp.	Harcourt	K162408	1 M	
7-15	Insp.	Harcourt	K1624120	2 M	
7-15	Insp.	Harcourt	K1623438	2 M	
7-15	Insp.	Harcourt	K1623397	2 M	
					Received in August
8-5	Insp.	Boston	K4110860	New	
7-6	Insp.	Spokane	K411125	1 M	
7-24	Insp.	Seattle	K4110460	3 M	
8-14	Insp.	Rochester	K1011138	15 M	
6-26	Insp.	Los Angeles	K1618709	12 M	
8-18	Insp.	Milwaukee	K4110152	3 M	
8-9	Insp.	Boston	K1621938	9 M	
8-7	Insp.	Boston	K1622414	9 M	
8-21	Insp.	Dallas	K1619313	1 Y	
8 2	Insp.	New York	K417657	1 Y	
8-2	Insp.	New York	K419131	4 M	

FIG. 12—SPECIMEN PAGE FROM THE SERVICE-COMPLAINT FILE
On These Pages Are Entered the Information Received on the Inspection Reports or Any Complaints Reported by Letter

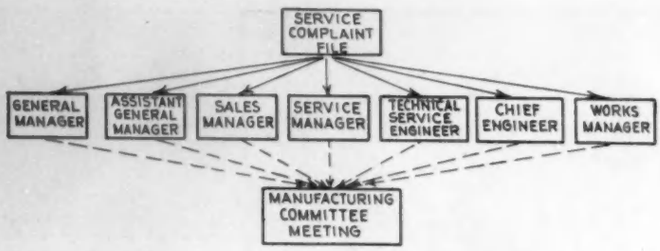

FIG. 13—SOLVING THE SERVICE-COMPLAINT PROBLEM
Copies of the Service-Complaint File in Loose-Leaf Form Go to Various Interested Members of the Organization. These Books Are Brought Uptodate on the First of Each Month by the Service Department and Returned with a Memorandum Calling Attention to the Most Serious Causes of Trouble

office or distributor to make certain that the complaints registered are corrected as soon as possible. Our correspondence on these complaints is kept active until we are satisfied that they have been cared for properly.

FACTORY ROAD-MEN

To keep in close touch with field service-conditions, we maintain a crew of four traveling service representatives who call on the branch offices, distributors and dealers in their respective zones approximately once every 3 to 4 months. Fig. 11 shows these zones, which contain approximately the same number of trucks, although their areas vary considerably. We also have two field men in reserve at the factory to answer emergency calls when necessary. These field service-men send us written reports of the calls they make and, when they encounter unusual troubles, they not only send service-inspection reports to the factory but, usually, they write special letters describing the troubles in detail. We maintain the usual follow-ups on such cases to be sure that the troubles have been corrected permanently. Incidentally, we have obtained some fine letters from customers who praise the work of these men and the interest displayed by the factory in helping to care for such complaints.

FIG. 14—TESTING A SHAFT RETURNED AS DEFECTIVE
The Records of the Claim Division Provide Information Relative to the Reported Failure of Parts or Assemblies. Before Credit Is Given for Any Parts Returned Because of Alleged Defects They Are Tested by Men under the Direction of the Manager of the Claim Division

SERVICE-COMPLAINT FILE

All the complaints described are recorded in the service-complaint file by the technical division of the service department. Fig. 12 is a reproduction of a page from this file. In reality it is an index of all complaints, listed according to the divisions on the service-inspection report, and contains the date of complaint; the kind of report, whether a letter or an inspection report; the source of complaint, whether from a branch office, a distributor or an operator; the chassis number; the length of time in service; the engine number, if the complaint refers to engine parts; and a brief summary of the complaint.

Having provided a means of getting this information together at the factory, the next step is to place it in the hands of those whose duty it is to correct or prevent the troubles reported. Fig. 13 shows how this is accomplished.

Copies of this complete file in loose-leaf form have been made for the general manager, the assistant general manager, the sales manager, the service-manager, the chief engineer, the works manager and the technical-service engineer. On the first of each month these books are sent to the service-department office and are brought uptodate for the preceding month. The technical division then returns these copies to the persons already named, with a memorandum directing their attention to the most serious causes of trouble. Thus, the service-complaint file embodies in compact and accessible form the latest information on complaints received from all available sources, and is looked upon as most dependable and valuable.

FACTORY SERVICE-CONFERENCES

Information as to the performance of our trucks and methods of servicing them is also obtained from three types of service conferences, minutes of which are kept and furnished to the persons already named. About Oct. 1 each year, we invite the service-managers of our branch offices to come to the factory to discuss troubles encountered in the field and the best ways to correct them. These annual conferences last for 3 or 4 days, and are conducted jointly by our service-manager and the chief engineer. The most successful method of getting the information desired relative to troubles has been to furnish each delegate with a parts book for each model of vehicle, and to go through it page by page asking for comments and criticisms on the various assemblies and parts described. The meeting of branch-office service-managers is followed a week later by a similar conference of distributors' and dealers' service-managers. Stenographic notes are taken and the minutes of these sessions are sent to the general manager and to department managers. Later, these are discussed with them by the service-manager and his associates.

We plan the routes of our traveling service-representatives so as to bring them together at the factory approximately once every 3 or 4 months, for from 7 to 10 days. During that time, we conduct a service conference following much the same procedure as at the large annual

conferences. Minutes are kept that are sent to the general manager and to the department managers with requests for comments and criticisms and for corrective action where possible. After the latest developments are discussed and policies are agreed upon, the road-men return to the field to carry out their work of educating the personnel of our field service-stations.

Field Meetings

Based upon the information obtained while at factory conferences, and sent to our representatives while in their respective territories, our road-men hold local meetings with the service departments of our branch offices and distributors, following in general the same procedure as already described. Notes made at these meetings are forwarded to the factory. There they are transcribed and sent to the general manager and to department managers. Complaints from this source are also listed in the service-complaint file.

The notes of all three types of conference are filed in our technical-service division and become the basis of following-up the engineering, the production and the purchasing departments for improvements, as well as for reports from the service-manager at the manufacturing-committee meetings. The necessary contact is maintained with the engineering department through our technical service-engineer.

Analysis of Parts Returned from the Field

The records of the claim division constitutes an important means of securing information relative to the reported failure of parts and assemblies in our trucks. Many of these records are included in the service-complaint file. These claim sheets are filed separately and, if we desire to analyze the number of parts or assemblies returned within a given period, the records are available for this purpose.

GENERAL MOTORS TRUCK COMPANY

SERVICE DEPARTMENT

RECORD OF PARTS CREDITED, 1924

Part No. 610141 Connecting Rod Model K16.

Cr. No.	Amt. Cr.	City	Cr. No.	Amt. Cr.	City
B-3513	--	N.Y.City.	A-4391	--	Detroit.
B-3510	--	N.Y.City.	B-3464	--	N.Y.City.
A-4334	--	Detroit.	A-4406	--	Pittsburgh.
S-68	--	Seattle.	C-737	--	Atlanta.
B-3406	--	N.Y.City.	R-48	--	Minneapolis.
A-4370	--	Rochester.	B-3486	--	New York.
E-297	--	Dallas.	B-3488	--	N.Y.City.
F-1874	--	Phila.	C-698	--	Atlanta.
D-801	--	Ind'pls.	B-3522	--	N.Y.City.
S-80	--	Seattle.	A-4517	--	Rochester.
R-56	--	Minneapolis.	F-1935	--	Philadelphia.
TOTAL	--			--	
				--	
			GRAND TOTAL	--	

Fig. 15—Record of Parts Credited as Defective
Each Part Has a Separate Sheet on Which the Credit Number and the City Are Listed. This Sheet Shows the Credits for the Connecting-Rod of a Truck for the Year 1924

GENERAL MOTORS TRUCK COMPANY

Service Department

Analysis of Parts Credited and Disbursed

Part No.	Name	Model	Dist. First Half	Cr. First Half	Dist. Last Half	Cr. Last Half
		YEAR 1921				
11-65	Bushing	15-16-21 23-26-31	---	---	---	---
11-219	Bushing	21-23-31-41-71-101 K41-K71-K101	---	---	---	---
		YEAR 1922				
11-186	Bushing	23-23A-31-41-K41	---	---	---	---
11-213	Bushing	71-101-K71-K101	---	---	---	---
11-219	Bushing	21-23-31-41-71-101	---	---	---	---
11-254	Bushing	K16-K41-K71-K101	---	---	---	---
11-261	Bushing	K15-K16	---	---	---	---
		YEAR 1923				
11 186	Bushing	23-23A-31-41-K41	---	---	---	---
11-213	Bushing	71-101-K71-K101	---	---	---	---
11-219	Bushing	21-23-31-41-71-101 K41-K71-K101	---	---	---	---
11-254	Bushing	K16-K41-K71-K101	---	---	---	---
11-255	Bushing	K16-K41-K71-K101	---	---	---	---
11-256	Bushing	K41	---	---	---	---
		YEAR 1924				
11-186	Bushing	23-23A-31-41-K41	---	---		
11-219	Bushing	21-23-31-41-71-101 K41-K71-K101	---	---		
11-256	Bushing	K41	---	---		
11-261	Bushing	K15 K16	---	---		

Fig. 16—Analysis of Parts Credited and Disbursed
This Sheet Gives a Record of the Number of Parts Credited as Compared with the Number Disbursed for a Period of 6 Months. A Copy of This Summary Is Sent to the Chief Engineer and Is Taken into Consideration when Recommending Changes or Improvements in Service Parts

Before credit is passed for parts returned because of alleged defects, they are inspected and tested by competent men under the direction of the manager of the claim division. Fig. 14 shows a tester who is checking the hardness of a shaft. Advice from the assistant general manager, the production manager and the chief engineer, as well as from our suppliers, is frequently asked in making disposition of our claims. Since this division is directly responsible to the service-manager, he is in a position to give accurate and dependable information to the manufacturing committee on current troubles when requested.

Fig. 15 shows how we keep records of parts credited as being defective. To compare the number of parts so credited with the number of parts disbursed in a given period, we make a summary every 6 months by parts or assemblies for our various models. Fig. 16 shows a page from this report for the years 1921 to 1924 inclusive. A copy of this summary is sent to the chief engineer and is taken into consideration when asking recommendations for changes or improvements in service parts.

Study of Parts Disbursements

To check the possibility that parts or assemblies may not be standing-up as they should in service, our stock-ledger division is constantly studying the records of receipts and disbursements. If the disbursements for any parts or assemblies are abnormal or excite our suspicion, we immediately try to learn the cause or causes for their heavy movement and sometimes discover that, by mistake, we have allowed defective parts to get into the field. In this event, we take the necessary steps to correct the trouble and replace the defective stock, whether in the field or at the factory, as soon as possible. With the same object in view, our branch offices and distributors are constantly watching the movement of their parts stock. If they have cause to suspect the

quality of any parts due to the necessity of ordering them too frequently from the factory, they notify us and we immediately start an investigation. Any unusual condition disclosed by these analyses is brought to the attention of the service-manager.

Reports from the Service-Manager

From the foregoing records the service-manager is able to prepare reports of definite value in respect to individual parts or assemblies which may be giving trouble, and to bring the necessary pressure to bear through the meetings of the manufacturing committee as well as other personal contact with the various departments of the company. The result is that we are able, not only to maintain the quality of our product, but to make improvements where necessary. These methods enable us also to secure the benefit of many valuable suggestions from our field service-stations in respect to methods of servicing our trucks in the field.

Summary

It is evident from the foregoing discussion that we use our service records as far as possible both at the factory and in the field. We try to make a record of our experience in producing and in servicing our trucks so that our service department through its voice in the manufacturing committee and in every other way contributes to the betterment of our product. The service engineer attached to our technical division follows-up the complaints recorded and, in connection with our engineering department, works out practicable remedies. Bulletins are then issued to our field organization, notifying our service-stations of improvements in the parts themselves or in methods of service. Through a continuous process of education carried on by our service road-men with our field service-station personnel, we are able to utilize the information disclosed through these records.

Results Accomplished

Through the gradual development of these methods, our service department has accomplished certain results of definite value. At the factory, we find that the other departments are more and more turning to the service department for dependable information in respect to the quality and performance of our product, and we are able to secure a degree of willing cooperation from them which we have never before enjoyed. We are able to assist our purchasing department in handling difficult problems with our suppliers, and we are frequently called into conference in making important decisions with reference to purchased materials.

Finally, the management of our company is turning to the service department for more and more information for use in establishing the general policies of the company. In the field, the results accomplished have been no less gratifying. Representatives of the service department are received with great favor wherever they go, since they not only bring information which makes the work of the field service-station easier and more dependable but they are looked upon at the factory as the spokesmen of our field service-stations in securing relief from various troubles.

FINAL REPORT ON THE 1924 CALIFORNIA AIR-CLEANER TESTS

(*Concluded from page* 371)

Two standard test-runs are usually given. They are the service run and the normal-load-and-speed run. In the service run the speed and load are varied through rather wide limits, such as might occur when a truck engine is required to extricate a load from a sandy spot or a tractor to pull a plow through hard-packed soil. Idling, backfiring, quick pickup with wide-open throttle, starting and stopping may be features in this test. Speed and load are brought to normal before the dust feeding begins and again after the 50-gram portion has gone in, to enable taking of the vacuum readings. In the normal run a constant brake-load of 20.4 hp. at 1200 r.p.m. is maintained. The rate of dust feed is 50 grams in about 30 min. for both service and normal runs.

A third test, which is called the fill-up test, is usually applied to cleaners designed, or presumably usable for, tractors. The results of this test are summarized in Table 4. It is not intended as an accurate test and if assumed to be accurate it might do great injustice to some cleaners. The object is to give a general indication of how a given cleaner might act if subjected to gross neglect and abuse. In this test from 1 to 10 lb. of a coarser standard dust, known as No. 2, is fed in rapidly through a funnel. When an air-cleaner passes this test without much loss of efficiency or increase in vacuum, its ability to stand up under abuse is supposed to be fairly well established. When, however, a cleaner *fails* in a test lasting from 10 to 30 min., to handle satisfactorily an amount of dirt that even under severe conditions would require many hours to accumulate, the test should be regarded as *inconclusive*, to say the least.

Other special tests are run as circumstances require. These include: (*a*) a light-load test at 9 hp. and 800 r.p.m. for cleaners intended for certain small cars or tractors; (*b*) a low-level test for wet-type or oil-type cleaners so constructed as presumably to be affected by the liquid level; and (*c*) a chaff test, vacuum measurement only, for cleaners needing but lacking screened inlets.

Other tests, some of which cannot be made readily in the laboratory but which are of the utmost importance, might have as their objects to determine (*a*) how long the cleaner will last in normal service; (*b*) how long the cleaner will continue to function if given no attention; (*c*) how much work, or time, would be needed to keep the cleaner in proper working condition throughout its life; (*d*) how great is the variation in efficiency among individual cleaners of any given make and model due to unworkable design causing too great a difference between the toolroom model and the manufactured article, poor workmanship, or too great tolerance limits in manufacture; (*e*) what happens if the cleaner is manipulated in any way while the engine is running; (*f*) what happens if, as might occur in threshing, the cleaner must be cleaned out or refilled with water or oil but it is not economically feasible to stop the engine; and (*g*) what are the weak places in the cleaner's construction, to what accidents it is especially vulnerable, and what are its pet tricks or foibles.

Industrial Standardization[1]

By F. L. Rhodes[2]

FOR upward of 30 years I have been connected with standardization work within one industry, the Bell Telephone System. There is a great breadth and diversity within that branch of standardization work alone. The telephone industry throughout the world is not universally standardized. Within the United States, which has 6 per cent of the world's population and 63 per cent of the world's telephones, standardization has been a vital factor in the development of the telephone art from the beginning. To obtain a picture of what happens in a telephone system in the absence of standardization, I shall briefly describe some of the conditions that have obtained in the telephone system of Paris, France, until very recently.

It has been said that in France, telephoning is little more than an adventure in a complex of silence and blasphemy. There the telephone subscriber has bought his instruments from some manufacturer. The Government Telephone Administration has approved about 150 types of instrument made by about 25 different manufacturers. All manufacturers of instruments have done their best to get new types approved, and to sell them to subscribers. From time to time some of these manufacturers have discontinued making certain types; sometimes because it did not pay to make them any longer and sometimes because the manufacturer failed and went out of business. That put the subscriber in a bad position, as frequently he could no longer get any parts for replacement.

Although the subscriber in France buys his instruments, they are installed by Government employes and the Government maintains them. It has been found difficult to familiarize the inspectors with 150 different types and also difficult for maintenance employes to carry all the parts necessary for repairs. When the subscriber has some difficulty with his service, he reports it to the telephone administration and in course of time it sends a man to the subscriber's premises to make an inspection. He often reports that the difficulty is not in the Government lines, but that it is in the subscriber's instrument; perhaps he tries to correct the fault. If he does not succeed, the subscriber is told that he has a bad set and should take it up with the manufacturer. So the subscriber says to the manufacturer "That set you sold me such and such a day is a bad one. What are you going to do about it?" Then the manufacturer will send someone around to make an examination of the set. He often reports that the difficulty is not in the set at all, but is in the Government line. That sort of correspondence sometimes has passed back and forth two or three times. The result has been a great loss of time to the subscriber and an inconvenience to all other subscribers who want to connect with him.

With so many types of instrument it has been found impossible to establish standards of transmission; so it very often happens that, while one conversation may be good, perhaps the next one is very poor. In the absence of standards of transmission it has not been possible to use the minimum amount of copper in trunk lines.

In the United States, this state of affairs has been avoided in the telephone plant by means of standards. The basis of our work of standardization has been that uniform apparatus and methods and materials are desirable because standardization

(1) Makes the best available for all
(2) Reduces cost because, when all companies use the same things, they can be manufactured in the largest quantities and uniformity in output contributes to economies in production
(3) Reduces the cost of carrying stocks of materials and the cost of maintenance and repairs, because fewer parts have to be carried
(4) Reduces the cost of instruction of new employes because there are fewer things to get acquainted with
(5) Reduces accounting costs because there are fewer types and sizes of material to keep track of
(6) Minimizes complicated engineering and operating problems that might result from intercommunication between widely divergent systems and apparatus
(7) Renders enormous supplies of materials and labor available in emergencies
(8) Greatly facilitates development work. If everything varied from everything else, there would be no definite point of departure from which to start to improve

The Requisite Nature of Standards

We have not found it advisable to have merely one standard for each thing and to try to force the business arbitrarily to conform to it. We do have as many standards as varying conditions require. These standards are not static; they are dynamic. We change our standards whenever it is advantageous to do so, and we clearly recognize that special conditions may justify departure from all of them. We are dealing, in the telephone business, with a living organism, a constantly growing thing, and we must, and do, at all times, keep our standards of all kinds under revision to see whether they stand the test that each day applies to them.

Our continuous revision of standards is something more than making verbal changes in the language of specifications or reducing the amount of material by arbitrary alterations in dimensions or quality. All our specifications, in the last analysis, are based upon economic considerations or considerations of service. Relative costs of material and of different grades of the same material are subject to change; sometimes more rapidly than at other times; and, when the market price of some of those which have been specified becomes excessive, other materials or grades of material become more economical, if technically satisfactory.

Changing from one material or from one grade of material to another usually involves experimentation and development work, and often requires new inventions. Frequently we find that even a minute change from one dimension to another, as in the case of the thickness of a cable sheath or the thickness of the insulation on a wire, can be made safely only after careful experimentation and preliminary trials, sometimes on an extended scale.

It is always possible to reduce first costs at a sacrifice of service or annual charges. The solution of our problem requires that we make these reductions without such sacrifices. This has been a guiding principle in our standardization work and the results have been of great importance to the public.

Specifying Performance Requirements

In many cases it has been our experience that flexibility of production has been obtained and the path to further improvements kept open by specifying, so far as possible, the performance requirements for completed things. An example of this would be specifying the electrical properties of an insulating compound, such as its insulation resistance, dielectric strength and specific inductive capacity, rather

[1] Presented at a meeting of the American Engineering Standards Committee.

[2] American Telephone & Telegraph Co., New York City.

than the percentages and grades of different rubbers, oils, waxes and fillers that may enter into its composition.

Specifications for some insulating materials are in existence which rigidly specify composition. From our contact with manufacturers, we have found a general opinion to exist that these requirements are not the best that could have been devised, from the standpoints of cost, electrical properties or durability, and that such requirements may be fully complied with and yet inferior material produced. Under the plan of specifying results, we have had a number of manufacturers preparing wires under the same specifications. No two of these manufacturers are employing the same insulating compounds in the same proportions, and yet, after a number of years' experience with each of them, we are unable to point out one of these compounds as being distinctly better than the others. This feature has its advantages from the standpoint of diversifying the raw material demand. Thus, during the war period, one of our manufacturers was inconvenienced by being unable to obtain from his accustomed source of supply the principal mineral filler used in his insulating compound. Our supervisory tests indicate that his product was failing to meet specification requirements and inspections at his plant were temporarily discontinued. Meanwhile, other suppliers, not so handicapped, were proceeding normally.

The specifying of composition in such materials as rubber insulating compounds is also a deterrent to the manufacturer in his desire to improve his own product. Recently a manufacturer, whose research facilities along his own line are very complete, gave us the results of tests involving the preparation of several hundred samples of a special wire. In this case, working along parallel lines, we had already arrived at a solution of the problem which showed some advantages over this manufacturer's proposal. Such cooperation, however, deserves the purchaser's encouragement and an effective way of extending it is the drafting of specifications in such a way that improvements of mutual advantage can be most readily developed.

Mechanical Tests and Composition Requirements

In specifications for hardware, we depend upon such mechanical tests as can be made by the inspector in connection with his examination for dimensions and assembly details. We have operated on the basis of omitting composition requirements for a number of years, and have found it desirable to resort to analyses in only a few cases where isolated failures have made thorough investigation of the failing pieces necessary.

There are, of course, some materials to which tests to determine suitability are not so readily applied, as to those referred to above. Typical of these materials are paints and timber preservatives; but, even for these materials, we have found it practicable to eliminate all but a few fundamental composition requirements. Thus, we have purchased paint in large quantities without specifying the composition of the pigment, depending upon color, fineness and insolubility to indicate acceptable characteristics. Under this arrangement, the chemical tests resolve themselves into a fairly simple determination of the purity of the vehicle.

Flexibility Necessary in Standardization

In closing, I should like to emphasize the disadvantages in allowing standards to become so crystallized and set that their revision becomes a difficult and time-consuming process. *Standardization is a useful servant but a bad master.* If improperly used, in a rigid, uncompromising way, standardization may fetter progress. If properly used, standardization will be found to be a valuable aid to progress. Whether standardization becomes a hindrance or an aid to progress will, in my opinion, largely depend upon the degree of flexibility of standards that is maintained, which involves a working arrangement so set up as to facilitate revision, and the full utilization of this arrangement by making revisions whenever, this can be done advantageously from an economic point of view.

MEETINGS OF THE SOCIETY

(*Continued from p.* 282)

In the average investigation, the two operations proceed concurrently, a new measurement requiring revision of the previous analysis, and the revised analysis pointing to the need for new measurements. Improved instrumentation usually leads to new results, by permitting either more accurate measurements, or measurements under new conditions. It is usually found, after a problem has been solved, that the successful investigator has so arranged his study that he has been able to make a new and proper evaluation of the controlling factors. To do this, new instruments have been used, or new methods of using old ones have been put into effect.

In general, the problem in the design of electrical instruments is to find an electrical device supplying current, voltage or frequency proportional to and caused by the quantity to be measured; then a suitable indicating or recording instrument must be chosen to go with it.

Vibration Recorder Demonstrated

After discussing briefly the Farnboro electric engine indicator, Mr. Hunt explained and demonstrated the action of an electrical instrument, developed under his direction, that is adapted to the investigation of torsional vibration of shafts. Essentially, the instrument includes in its construction a small flywheel carried on good bearings on the shaft to be studied and driven by the shaft through relatively weak springs. This flywheel will tend to rotate at uniform speed, and relative motion between the flywheel and the shaft will occur whenever the shaft is not running with uniform angular velocity. By the mounting of the main parts of a small generator magnetic circuit in the flywheel where they will contribute to the inertia, and by the mounting of windings on the shaft, within which windings voltage is generated by the flux change, when relative motion between the shaft and the flywheel occurs, a simple device is established for detecting the torsional vibrations that are set up in the shaft. The current, taken off through two slip-rings with corresponding brushes, serves to operate the element of an oscillograph which furnishes a record of the phenomena. A second element of the oscillograph is used to record other data such as the time of the spark or the primary ignition-current.

Attention was called to the necessity of exercising due care in the interpretation of the records thus obtained. Suitable methods of calibration have been developed.

Measurement of Sound

Perhaps the most interesting part of Mr. Hunt's address related to the study of sounds and noises. Improved instrumentation was said to offer means for materially reducing the cost of noise investigations that have in the past depended largely upon the use of the sense of hearing to obtain reliable information. Several methods were shown for timing a given noise by converting the sound vibrations into electric currents of the equivalent wave form and then switching the connections in and out by a device synchronized with the engine rotation.

A piezo-electric method for detecting vibrations was described. In this method, advantage is taken of the property

of a Rochelle salt crystal to set up within itself an electric charge whenever it is twisted. If the crystal is properly mounted so that it is affected by the vibrations to be studied, the potential changes may be observed or recorded and interpreted in their relation to the vibrations. The circuit used for making measurements of vibration intensity includes a timing switch by which the time of the noise with respect to the engine cycle can be easily determined, provided the noise stands out from the other sounds. The impulse from the crystal is carried through an amplifying tube and transformer and is applied to a detector tube with a telephone in the plate circuit. A bias battery is provided which may be used if only relatively coarse readings are required. The greater the disturbance to the crystal, the greater the impulse applied to the final tube, and the greater the bias voltage, negative to the grid, required to prevent this impulse from finally reaching the telephone.

A Loudness Evaluator

The apparatus described above is not adapted to the study of humming or howling noises like those that emanate from gears or fans. Consequently an instrument was developed to give a pointer reading with a definite relation to the energy in the air vibrations from various sources of noise. This instrument involves a transmitter or device for converting air vibrations into alternating currents, an amplifying system, and a detector system, the last-named being arranged so that readings proportional to the electric currents are produced. Fig. 1 shows the electrical hook-up with the various elements represented by conventional symbols. This arrangement can be simplified to use only two vacuum tubes. A motor-driven siren may be conveniently used for calibration.

In his address Mr. Hunt described other instruments, including the Bureau of Standards telemeter which has already been discussed in The Journal.[1] Various possible applications of this instrument were considered.

It is hoped that the paper may be presented in full in a forthcoming issue of The Journal.

[1] See The Journal, June, 1924, p. 582.

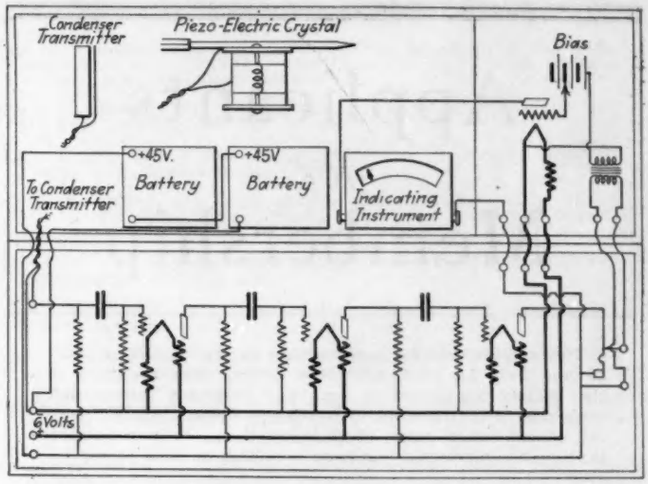

Fig. 1—General Motors Apparatus for Noise Study
The Circuits Include Four Three-Electrode Vacuum Tubes with Resistances, Capacities and Other Elements Shown by Conventional Symbols

MEETINGS AT SAN FRANCISCO

At the meeting held on Feb. 26, in San Francisco, the subject for discussion was Efficiency of Air-Cleaning Devices. The paper was prepared by A. H. Hoffman, of the division of agricultural engineering, college of agriculture, University of California, and was based on the two papers, Air-Cleaners on Trucks in Service and Final Report on 1924 California Air-Cleaner Tests, that he presented at the 1925 Annual Meeting. Its delivery by the author at this time and place afforded the interested engineers of this locality a welcome opportunity to obtain these air-cleaner data at first hand and to discuss their many features of engineering importance.

On March 26, L. Wagner will present a paper dealing with the Effects of Engine Operation on Lubricating Oil.

THE NIGHT FLYERS

As New Yorkers are just about sitting down to their 7 o'clock dinners the Air Mail, which leaves this town at 10 in the morning, is landing at Maywood Field, on the outskirts of Chicago; and while many of them are still wrapped in sleep that same mail, having flown above a string of blinking lights and swinging beacons across the prairie country, is drawing near the Rockies, to hop them and the deserts and Sierras, and slide down across the Sacramento Valley to San Francisco by 5:45 of the afternoon.

As New Yorkers are opening their office desks at 9 in the morning the mail that left the Pacific coast the day before is just drumming into Chicago across the frosty prairies from the West, to reach New York City just about as those offices are closing at 5:05 in the afternoon and their occupants are hurrying home.

For several months now this night flying has been going on, a 34-hr. 45-min. service westward, a 31-hr. 35-min. service eastward, day in and day out, blow high, blow low, through blizzards and through rain. Some of our excitable neighbors seem to forget this bit of progress as they emit their roars, every now and then, to the effect that we have no workable planes in this Country and are accomplishing nothing in the air. As a matter of fact, the work of the Air Mail pilots is something for every one to be proud of, and the morale of that branch of the service could scarcely be better.

There are, nevertheless, things yet to be done. Night flying, even with the best of lights, has its dangerous landings, and the night-flying airplane differs from that used for day flights in that it ought to have a slow landing-speed. It must be capable both of high speed in the air, say 130 m.p.h.; and of slow speed, say 40 m.p.h, as it hits the earth. The machine with which we are doing our night flying now meets the first of these qualifications, but not the second. It cannot land at a slower speed than about 60 m.p.h.—*New York Herald-Tribune.*

FOREIGN MARKETS

Far in the lead among passenger-car markets for both the United States and Canada stands Australia. With that great continental buyer at the head of both lists, their similarity practically ceases. The four countries following Australia in the United States list are Argentina, Canada, Mexico and Cuba. The countries which occupy similar positions in the Canadian table are New Zealand, the United Kingdom, British India and British South Africa. The chief difference between the markets for the United States and Canada thus results from the supplying of British areas by Canada.

In trucks, Japan retains first position for the United States, having first reached this leading place in 1923. It is interesting to note that Japan took 3053 trucks from the United States in 1924, while Australia, the leading market for Canada, took 5837.—*Commerce Reports.*

Applicants *for* Membership

The applications for membership received between Jan. 15 and Feb. 14, 1925, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

BAKER, CARROLL W., garage foreman, Bureau of Power & Light, *Los Angeles.*

BEVERLY, HUGH L., manager, Standard Oil Co. of California, *San Francisco.*

BILLINGS, JOSEPH, sales engineer and manager, Elk Sales Corporation, *New York City.*

BLANCHARD, DONALD, field editor, Class Journal Co., *Detroit.*

BOYER, V. W., designer, Cleveland Automobile Co., *Cleveland.*

BUNTING BRASS & BRONZE CO., *Toledo.*

CAMPBELL, WORTHINGTON, lawyer, Redding, Greeley, O'Shea & Campbell, *New York City.*

CLAYTON, M. L., general service superintendent, Flippen Auto Co., *Dallas, Tex.*

CREDNER, LOUIS, principal, Y. M. C. A. Automobile School, *New York City.*

DOLNITSKY, NATHAN, instructor in automobile mechanics, Lane Technical High School, *Chicago.*

DYKE, S. E., purchasing agent, Sharples Separator Co., *West Chester, Pa.*

ELLIOTT, ALBERT GEORGE, Rolls-Royce, Ltd., *Derby, England.*

EWING, STANLEY W., engineer, National Malleable & Steel Castings Co., *Cleveland.*

FIELD, EUGENE W., sales and lubricating engineer, Western Oil Refining Co., *Indianapolis.*

FLETCHER, AUSTIN B., consulting highway engineer, bureau of public roads, Department of Agriculture, *City of Washington.*

GEERTZ, ERIC, repairman, Franklin Service Station, *Auburn, N. Y.*

GIBFORD, CHARLES W., experimental engineer, Schwarze Electric Co., *Adrian, Mich.*

GRAHAM, JOHN, president, Holbrook Co., *Hudson, N. Y.*

HAMILTON, C. E., president, Automotive Gear Works, Inc., *Richmond, Ind.*

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Applicants *Qualified*

The following applicants have qualified for admission to the Society between Jan. 10 and Feb. 10, 1925. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member.

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